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ASL-CR-80-0143-2

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ASL-DUST: A TACTICAL BATTLEFIELD DUST CLOUD AND PROPAGATION CODE

VOLUME 2 - USER'S MANUAL

JUNE 1980

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Under Contract: DAAD07-79-C-0143

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(19) REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER ASL-CR-80-0143-2	2. GOVT ACCESSION NO. AD-A087 630 / 3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) (6) ASL-DUST: A Tactical Battlefield Dust Cloud and Propagation Code. Volume 2. User's Manual.	5. TYPE OF REPORT & PERIOD COVERED (9) Final Report
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) (10) James H. Thompson (12) 149	8. CONTRACT OR GRANT NUMBER(s) (15) DAAD07-79-C-0143
9. PERFORMING ORGANIZATION NAME AND ADDRESS General Electric Company—TEMPO 816 State Street Santa Barbara, CA 93102 346420	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS (16) DA Task 1L161102B53A
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Electronics Research and Development Command Adelphi, MD 20783	12. REPORT DATE (11) June 1980
	13. NUMBER OF PAGES 142
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) Atmospheric Sciences Laboratory White Sands Missile Range, NM 88002	15. SECURITY CLASS. (of this report) UNCLASSIFIED
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Melvin G. Heaps ASL Contract Monitor

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Battlefield dust
Optical transmission
Millimeter transmission
Infrared transmission
Electro-optical propagation
Dust model
Particulates

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

ASL-DUST is a computer code that models: (1) the dust clouds generated by tactical munitions impacting the ground, and (2) the propagation of electro-optical signals through the resulting dusty environment. Volume 1 describes the models in ASL-DUST and compares the code results with the experimental data base. This volume, the User's Manual for ASL-DUST, discusses the computer subroutines and the input-output parameters, and provides a sample problem. A listing of the code is presented in the appendix.

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SECTION 1
INTRODUCTION

A wide variety of electro-optical (E-O) sensors are employed in the modern tactical battlefield environment. Dust clouds are generated when tactical munitions detonate at or below the ground surface. These dust clouds can be a major source of degradation for the battlefield performance of the E-O sensors. References 1 and 2 present models which have been developed for the munitions dust clouds and the propagation of E-O signals through the clouds. ASL-DUST is the computer program for these dust cloud and propagation models.

This volume, the User's manual for ASL-DUST, discusses the computer subroutines and the input-output parameters, and provides a sample problem. A listing of the code is given in the appendix.

ASL-DUST is written in Fortran IV and is comprised of about 4,500 cards. There are many comment cards to aid the programmer in understanding the internal workings of each routine. Approximately 28K of storage is required. A typical case with one dust cloud, one sight path, and eight calculation times takes about a third of a second on a CDC 7600 computer.

The inputs to the code are the burst parameters, transmitter-receiver parameters, soil and carbon parameters including size distribution and index of refraction, meteorological conditions, size groups of particulates, and the calculation times. The code first calculates the Mie propagation parameters (extinction, absorption, scattering, and backscatter mass coefficients) for each size group, for each particulate material, and for each frequency. Then at each calculation time the code finds the dust cloud position and spatial

mass distribution. The code integrates the mass penetrated within each particulate size group along each sight path (the path between each transmitter-receiver pair). Applying the previously calculated Mie propagation parameters, the code then computes the transmission of each signal along its sight path.

SECTION 2
THE COMPUTER ROUTINES

GENERAL INFORMATION

ASL-DUST is organized into an executive (main) program and a set of subroutines. The modular organization of the code is designed for maximum user flexibility. The user who wishes to modify some model parameter can do so by modifying the appropriate subroutine or by simply substituting his own subroutine. Moreover, many of the routines are complete within themselves and can be lifted and used for other purposes. For instance, the Mie routines form a complete detailed Mie calculation code.

This section briefly describes each of the eighteen ASL-DUST routines. Table 1 summarizes their major functions. More information concerning the detailed logical organization of the routines may be obtained from the listings of the Fortran source programs presented in the appendix. The method of preparing the inputs for ASL-DUST is discussed in Section 3.

COORDINATE SYSTEM

A three-dimensional Cartesian coordinate system is used. The x and y axes are horizontal and the z axis is the vertical direction (see Figure 1). Azimuths in the horizontal plane are measured clockwise from the y axis.

EXECUTIVE ROUTINE

This routine controls the sequence of operations for ASL-DUST. The routine first sets the tape numbers for input-output and the default values for the input quantities. It then reads the input for the first problem by calling INPUT. Next, the Mie propagation

TABLE 1. ASL-DUST COMPUTER ROUTINES

Name of Routine	Function
Executive Routine	Control program. Determines sequence of operations.
INPUT	Reads and writes the input quantities.
PGROUP	Control program for calculating the Mie propagation coefficients for each size group, for each particulate material, and for each frequency.
CGROUP	Performs preliminary Mie propagation coefficient calculations; sets up input for CROSS.
CROSS	Integrates over the size group.
MIE	Provides Mie efficiencies and scattering pattern for a single uniform spherical particle.
ANF	Evaluates a complex function used in Mie.
CUMNOR	Computes the cumulative function of the normal random probability distribution.
INITG	Evaluates the initial (t = 0+) properties of the dust clouds.
TIMECO	Determines the location and dimensions of the ideal massless size group.
TIMECG	Determines the location and dimensions of a given size group in the dust clouds.
PATH	Integrates the dust cloud mass density along each sight path.
DEPTH	Computes optical depths along each sight path. Prints output results.
ADDVEC	Adds two three-vectors together.
SUBVEC	Subtracts two three-vectors.
MULVEC	Multiplies a three-vector by a scalar.
DOTVEC	Scalar (dot) product of two three-vectors.
DSTVEC	Computes the distance between end points of two three-vectors.

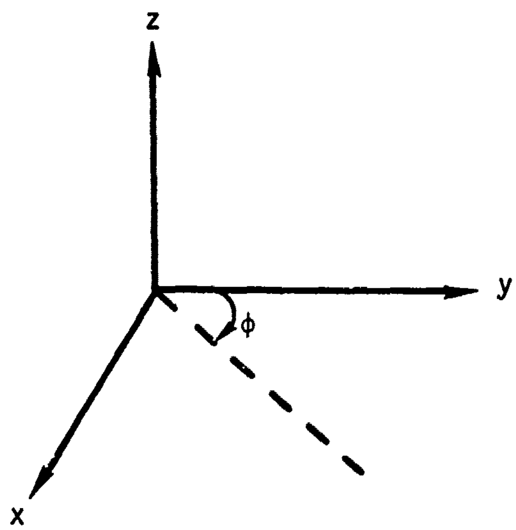

Figure 1. Coordinate system.

coefficients for each particulate material, size group, and frequency are calculated and stored by calling PGROUP. The initial (t = 0+) properties of the dust clouds from each burst are found by a call to INITG. Then for each calculation time and for each burst, the mass distribution of each size group is found by calls to TIMECO and TIMECG. For each sight path a call to PATH computes the group mass penetrated. A call to DEPTH then computes the optical depth along each sight path. After all calculations are complete the output is written out; the program then begins again by reading the input for the next problem.

INPUT

This routine reads the input quantities for each problem. After all input is read, the routine writes out the input data.

PGROUP

This is the control routine for calculation of the Mie propagation coefficients for each size group, each particulate material, and each frequency. The primary Mie parameters are the extinction, absorption, and scattering cross sections and mass coefficients averaged over a

size group. The routine first calculates the Mie propagation coefficients for each size group assuming that there is no mixing of particulates from other size groups. The size groups are ordered by size, beginning with the smallest. The coefficients for each group are calculated in turn until the extinction contribution of the present size group becomes negligible; the remaining larger size groups are not calculated and their coefficients are set equal to zero. This neglect of the insignificant size groups saves computing time. After all significant size groups are calculated, the routine then writes out the unmixed propagation coefficient results.

The routine then recomputes the mass fractions and propagation coefficients in each size group by assuming a mixture of particle sizes. The mixing model is given in the fractionization section of Reference 2. The routine then writes out the mixed propagation coefficient results.

CGROUP

This routine does some preliminary Mie propagation calculations for a given size group. It sets up the input to routine CROSS.

CROSS

This routine evaluates the size group mean Mie propagation coefficients by integrating over the particle size probability distribution. CROSS calls routine MIE to evaluate the coefficients at a particular integrand point.

A new variable step length algorithm has been developed for the integration over particle sizes. The algorithm accounts for the rate of change of integrand magnitude with step length and the contribution of the step to the total integral. A rapidly changing integrand requires smaller steps, while a portion of the integral that contributes little to the total can be calculated with larger steps. The algorithm is designed to produce maximum accuracy with minimum computational time.

The equations solved in the routines are the following. The mean cross section per particle is

$$\bar{\sigma} = \frac{\int_{a_1}^{a_2} \frac{\pi a^2}{4} Q(a)P(a)\, da}{\int_{a_1}^{a_2} P(a)\, da} \quad \text{cm}^2 \text{ per particle} \quad , \qquad (1)$$

where

$\bar{\sigma}$ = average cross section per particle for scattering, backscatter, absorption, or extinction (cm^2)

a = particle diameter (cm)

a_1 = minimum diameter of particle size group (cm)

a_2 = maximum diameter of particle size group (cm)

Q(a) = Mie efficiency for scattering, backscatter, absorption, or extinction for a particle of diameter a

P(a) = size probability distribution (log normal, power law, or hybrid).

The normalized scattering pattern is

$$S_N(\theta) = \frac{1}{\bar{\sigma}_{SCA}} \int_{a_1}^{a_2} \frac{\pi a^2}{4} Q_{SCA}(a)P(a)S(\theta,a)\, da \quad , \qquad (2)$$

where

$\bar{\sigma}_{SCA}$ = average cross section per particle for scattering, given in Equation 1 (cm^2)

$Q_{SCA}(a)$ = Mie efficiency for scattering

$S(\theta,a)$ = normalized scattering pattern at scattering angle for a single particle of diameter a

$S_N(\theta)$ = normalized scattering pattern for the size group.

The scattering patterns are normalized so that

$$\frac{1}{4\pi} \int_{4\pi} S(\theta)\, d\Omega = 1 \quad . \qquad (3)$$

Hence an isotropic scattering pattern is identically equal to unity for all angles. The mass coefficient per gram of material in the size group is

$$\mu = N_T \bar{\sigma} \quad cm^2\ g^{-1} \quad , \tag{4}$$

where

μ = mass coefficient for scattering, backscatter, absorption, or extinction ($cm^2\ g^{-1}$)

N_T = total number of particles per gram of material in the size group (g^{-1}).

The integration strategy is the following:

$$I_T = \int_{a_1}^{a_2} I(a)\ da = \sum_{j=1}^{n} \int_{a_j}^{a_{j+1}} I(a)\ da \quad , \tag{5}$$

where

I(a) = integrand of the integral of interest.

The interval from a_1 to a_2 is broken up into a number of subintervals. For each subinterval we assume that the integrand can be described by a power law,

$$I(a) = I(a_j)\left(\frac{a}{a_j}\right)^x \qquad a_j \leq a \leq a_{j+1} \tag{6}$$

where

$$x = \frac{\ell n \dfrac{I(a_{j+1})}{I(a_j)}}{\ell n \dfrac{a_{j+1}}{a_j}} \quad . \tag{7}$$

Then the contribution to the total integral of this subinterval is

$$\Delta I_T = \int_{a_j}^{a_{j+1}} I(a)\ da \tag{8}$$

$$
= \begin{cases} \dfrac{I(a_j)a_j}{x+1}\left[\left(\dfrac{a_{j+1}}{a_j}\right)^{x+1} - 1\right] & x \neq -1 \\ I(a_j)a_j \; \ell n \; \dfrac{a_{j+1}}{a_j} & x = -1 \quad . \end{cases}
$$

The contributions of the subintervals are calculated and summed until either

(1) the diameter limits of the size group interval are reached, or

(2) the integral converges to its final value (the remaining unsummed subintervals are negligible).

The step size is chosen as the e-folding distance for the integrand:

$$
(\Delta a)_i = a_{j+1} - a_j = a_j\left[e^{\frac{1}{|x|}} - 1\right] \quad . \tag{9}
$$

With this step size,

$$
I(a_{j+1}) = I(a_j)\ e^{\pm 1} \quad , \tag{10}
$$

where the plus sign is for positive x and the negative sign is for negative x. In addition, for those cases where the integrand is decreasing so that the subinterval contributions are decreasing, the step size is increased. The increase is taken as the ratio of the previous contribution to the last contribution:

$$
(\Delta a)_j = a_j\left[e^{\frac{1}{|x|}} - 1\right]\frac{(\Delta I_T)_{j-1}}{(\Delta I_T)_{j-2}} \quad \text{if} \quad \frac{(\Delta I_T)_{j-1}}{(\Delta I_T)_{j-2}} > 1 \quad . \tag{11}
$$

MIE

This routine calculates the Mie efficiencies and scattering pattern for a given uniform spherical particle. This routine and its slave routine ANF were originally developed by the author for the WOE code, Reference 3. For completeness and reader convenience, the documentation is reproduced here.

We first present the formulas for the Mie solution (see any standard text for a derivation) and then the method used to solve the equations. Define the following quantities:

r = radius of the uniform sphere

λ = wavelength of the incident radiation

$\alpha = 2\pi r/\lambda$

= dimensionless size parameter

$m = m_R - im_I$

= complex index of refraction of the sphere (note that here we are using m instead of n, since by custom n is used as the order in the Mie formulas)

$Y = m\alpha$

σ_{SCA} = scattering cross section of the sphere

σ_{ABS} = absorption cross section of the sphere

$Q_{SCA} = \sigma_{SCA}/\pi r^2$

= scattering efficiency of the sphere

$Q_{ABS} = \sigma_{ABS}/\pi r^2$

= absorption efficiency of the sphere

$Q_{EXT} = Q_{ABS} + Q_{SCA}$

= extinction efficiency

$S(\theta)$ = scattering function. $S(\theta)\, d\Omega$ is the fraction of the incident unpolarized energy per unit area that is scattered into solid angle $d\Omega$, which is centered about the direction that makes an angle θ with the direction of the incident radiation (θ is the scattering angle).

The equations for the Mie solution are:

$$Q_{SCA} = \frac{2}{\alpha^2} \sum_{n=1}^{\infty} (2n+1) \left[|a_n|^2 + |b_n|^2 \right] \tag{12}$$

$$Q_{EXT} = \frac{2}{\alpha^2} \sum_{n=1}^{\infty} (2n+1)\ \mathrm{Re}\ (a_n + b_n) \tag{13}$$

(where Re signifies the real part of)

$$S(\theta) = \frac{1}{2}\left(\frac{\lambda}{\pi}\right)^2 \left\{|S_1(\theta)|^2 + |S_2(\theta)|^2\right\} \quad , \tag{14}$$

where

$$a_n = \frac{\alpha\Psi_n'(Y)\Psi_n(\alpha) - Y\Psi_n'(\alpha)\Psi_n(Y)}{\alpha\Psi_n'(Y)\xi_n(\alpha) - Y\xi_n(\alpha)\Psi_n(Y)} \tag{15}$$

$$b_n = \frac{Y\Psi_n'(Y)\Psi_n(\alpha) - \alpha\Psi_n'(\alpha)\Psi_n(Y)}{Y\Psi_n'(Y)\xi_n(\alpha) - \alpha\xi_n(\alpha)\Psi_n(Y)} \tag{16}$$

$$S_1(\theta) = \sum_{n=1}^{\infty} \frac{2n+1}{n(n+1)} \left\{a_n\pi_n(\cos\theta) + b_n\tau_n(\cos\theta)\right\} \tag{17}$$

$$S_2(\theta) = \sum_{n=1}^{\infty} \frac{2n+1}{n(n+1)} \left\{b_n\pi_n(\cos\theta) + a_n\tau_n(\cos\theta)\right\} \tag{18}$$

and

$$\Psi_n(z) = \left(\frac{\pi z}{2}\right)^{1/2} J_{n+1/2}(z) \tag{19}$$

$$\xi_n(z) = \left(\frac{\pi z}{2}\right)^{1/2} \left[J_{n+1/2}(z) + i(-1)^n J_{-n-1/2}(z)\right] \tag{20}$$

$$\pi_n(\cos\theta) = P_n'(\cos\theta) \tag{21}$$

$$\tau_n(\cos\theta) = \cos\theta\,\pi_n(\cos\theta) - \sin^2\theta \frac{d}{d\cos\theta}\pi_n(\cos\theta) \ . \tag{22}$$

The J's are spherical Bessel functions of complex argument and half-integer order. The P's are Legendre polynomials. Ψ and ξ are Riccati-Bessel functions, and π and τ are associated Legendre polynomials. Define an arbitrarily oriented plane containing the scattering sphere

and the incident radiation. Then for scattered radiation within the plane, the complex amplitude function $S_1(\theta)$ describes the scattering for an incident plane wave with vertical polarization (E perpendicular to the scattering plane); $S_2(\theta)$ is for horizontal polarization (E parallel to the scattering plane).

As might be expected from the complexity of the Mie equations, the numerical evaluation of Q_{SCA}, Q_{EXT}, and $S(\theta)$ for a given m and α is not, in general, a trivial task. The terms in the infinite series have to be evaluated and summed. The number of terms that have to be evaluated before the series converge depends primarily upon the size parameter α. Roughly, the number of Mie terms required is 1.5α; for large particles and small wavelengths, several hundred terms are often required before convergence.

The evaluation of the various orders of ξ_n, π_n, and τ_n is straight forward. We can use the well known recurrence relations of Bessel functions and Legendre polynomials to obtain

$$\xi_n(\alpha) = \frac{2n - 1}{\alpha} \xi_{n-1}(\alpha) - \xi_{n-2}(\alpha) \quad , \tag{23}$$

with initial values

$$\xi_o(\alpha) = \sin \alpha + i \cos \alpha \tag{24}$$

$$\xi_{-1}(\alpha) = \cos \alpha - i \sin \alpha \tag{25}$$

$$\pi_n(\cos \theta) = \frac{2n - 1}{n - 1} \cos \theta \, \pi_{n-1}(\cos \theta) - \frac{n}{n - 1} \pi_{n-2}(\cos \theta) \tag{26}$$

$$\tau_n(\cos \theta) = \cos \theta \left[\pi_n(\cos \theta) - \pi_{n-2}(\cos \theta)\right] - (2n - 1) \sin^2 \theta \, \pi_{n-1}(\cos \theta) + \tau_{n-2}(\cos \theta) \quad . \tag{27}$$

The initial values are

$$\pi_o(\cos\theta) = 0 \tag{28}$$

$$\tau_o(\cos\theta) = 0 \tag{29}$$

$$\pi_1(\cos\theta) = 1 \tag{30}$$

$$\tau_1(\cos\theta) = \cos\theta \tag{31}$$

$$\pi_2(\cos\theta) = 3\cos\theta \tag{32}$$

$$\tau_2(\cos\theta) = 3\cos(2\theta) \quad . \tag{33}$$

With the initial values, we can use the forward recurrence relations to generate the required terms to any order. The forward recursion technique for these three functions is stable and accurate.

To complete our numerical evaluation, we define the complex function

$$A_n(Y) = \frac{\psi'(Y)}{\psi(Y)} \quad . \tag{34}$$

With this definition, the Mie formulas for a_n and b_n can be written

$$a_n = \frac{\left(\frac{A_n(Y)}{m} + \frac{n}{\alpha}\right)\mathrm{Re}\left\{\xi_n(\alpha)\right\} - \mathrm{Re}\left\{\xi_{n-1}(\alpha)\right\}}{\left(\frac{A_n(Y)}{m} + \frac{n}{\alpha}\right)\xi_n(\alpha) - \xi_{n-1}(\alpha)} \tag{35}$$

$$b_n = \frac{\left(mA_n(Y) + \frac{n}{\alpha}\right)\mathrm{Re}\left\{\xi_n(\alpha)\right\} - \mathrm{Re}\left\{\xi_{n-1}(\alpha)\right\}}{\left(mA_n(Y) + \frac{n}{\alpha}\right)\xi_n(\alpha) - \xi_{n-1}(\alpha)} \quad . \tag{36}$$

The primary difficulty in evaluating the Mie formulas lies in the evaluation of $A_n(Y)$. Using the properties of the Bessel functions, we can write $A_n(Y)$ as

$$A_n(Y) = -\frac{n}{Y} + \frac{J_{n-1/2}(Y)}{J_{n+1/2}(Y)} \quad . \tag{37}$$

Thus, if we can evaluate the Bessel functions, say by forward recursion, $A_n(Y)$ can be evaluated. Alternately, we can use the recurrence relations for the ratios of the Bessel functions and write the recursion equation for $A_n(Y)$ itself as

$$A_n(Y) = -\frac{n}{Y} + \left(\frac{n}{Y} - A_{n-1}(Y)\right)^{-1} \tag{38}$$

with initial condition

$$A_o(Y) = \frac{\cos Y}{\sin Y} \quad . \tag{39}$$

The forward recursion technique for the evaluation of $A_n(Y)$ is very susceptible to error in at least four cases (Reference 4):

- When the argument is small
- When the argument is large, requiring a large number of orders
- When the imaginary value is larger than the real value
- For certain anomalous values.

The use of forward recursions to generate the consecutive orders of Bessel functions is a classic example of unstable numerical methods.

Many other techniques have been devised to generate the required Bessel functions or ratios. Most techniques involve some type of backward recursion. The values of the Bessel functions or the ratios are evaluated at a high order, and the backward recursion relation is used to evaluate the lower orders. The backward recursion does not have the instability of the forward method. However, care must be taken to preserve accuracy; some techniques lose accuracy even when using double precision arithmetic. Recently Lentz (Reference 4) has developed an algorithm for evaluating the Bessel functions and ratios that eliminates the weaknesses of the earlier methods. Lentz's algorithm uses a new technique of evaluating continued fractions that starts at the beginning rather than the tail and has a built-in error check. Using the method, any $A_n(Y)$ can be generated completely

independently of all preceding values with high accuracy. Readers are referred to Lentz's article for details.

We use Lentz's method to generate $A_n(Y)$ for n of order $\approx 1.5\alpha$ and then use the backward recursion relationship,

$$A_{n-1}(Y) = \frac{n}{Y} - \left(\frac{n}{Y} + A_n(Y)\right)^{-1} \quad , \tag{40}$$

to generate all lower orders. Using the forward recursion relations for the other functions, the a_n and b_n are calculated and infinite series summed until convergence. In almost all cases, convergence is reached before reaching the highest precomputed order of $A_n(Y)$. Otherwise Lentz's method is used to generate any additional needed terms.

Utilizing the Lentz algorithm, we have written a very compact computer routine that evaluates the exact Mie equations for Q_{SCA}, Q_{EXT} (and thus Q_{ABS}), and $S(\theta)$. The running time is quite reasonable for an exact calculation. For $\alpha = 1.2$, three orders are required for convergence, and the running time is 1 millisecond on a CDC 7600 computer. For $\alpha = 100$, 103 orders are required with a running time of 25 milliseconds.

ANF

ANF is a slave routine to MIE. ANF uses Lentz's method (Reference 4) to evaluate the complex function $A_n(Y)$ of Equation 37.

CUMNOR

This routine evaluates the following function:

$$\text{CUMNOR}(X) = \begin{cases} F(x) & x \le 0 \\ 1 - F(x) & x \ge 0 \end{cases} \tag{41}$$

where

$$F(x) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{x} e^{-\frac{1}{2}t^2} \, dt \tag{42}$$

= cumulative probability of the standardized normal random probability distribution.

To numerically evaluate CUMNOR(X) we use the approximation formulas of Reference 5. For $|x|$ less than 5 we use the polynomial approximation formula 26.2.17, and for $|x| \geq 5$ we use the asymptotic approximation formula 26.2.24.

For $-5 < x < 5$,

$$\text{CUMNOR}(X) = 1 - \frac{1}{\sqrt{2\pi}} e^{-\frac{x^2}{2}} \left[b_1 z + b_2 z^2 + b_3 z^3 + b_4 z^4 + b_5 z^5\right] \qquad (43)$$

where

$$z = \frac{1}{1 + p|x|}$$

$$p = 0.2316419$$

$$b_1 = 0.319381530$$

$$b_2 = -0.356563782$$

$$b_3 = 1.781477937$$

$$b_4 = -1.821255978$$

$$b_5 = 1.330274429 \quad .$$

The error in this approximation is less than 7.5×10^{-8}. For $|x| \geq 5$,

$$\text{CUMNOR}(X) = \left[\frac{\sqrt{4 + x^2} - |x|}{2}\right] \frac{e^{-\frac{x^2}{2}}}{\sqrt{2\pi}} \quad . \qquad (44)$$

At $|x| = 5$ the error in this approximation is less than 1.1×10^{-8} and decreases rapidly with increasing $|x|$.

INITG

The initial dust cloud is assumed to form instantaneously at burst time. This routine evaluates the following initial cloud parameters:

1. Total dust mass lofted in the main and base dust clouds.
2. Total carbon mass in the main and base dust clouds.
3. Initial radius of equivalent spherical cloud.
4. Initial radii of the main dust cloud in the artillery shell track direction, cross track direction, and vertical direction.
5. Initial radii of the main dust cloud in the wind track and cross track directions.
6. Main dust cloud rise rate constant.
7. Main dust cloud vertical diffusion constant.
8. Time delays before the wind begins moving the main and base clouds horizontally.
9. Mean wind velocities at the center of the initial cloud and at 10 meters altitude.

After evaluation the routine writes out most of the initial parameters.

TIMECO

The smallest particles in the main dust cloud rise with the ideal spherical cloud rise rate, transport with the wind velocity (after the initial time delay), and diffuse with the ideal cloud diffusion rate. The heavier particles will rise at a slower rate and eventually fall out of the cloud, will lag behind the smaller particles in horizontal wind transport, and will diffuse at a slower rate. At a given time t after burst, this routine evaluates the following parameters for the ideal zero mass particles in both the main and base dust clouds:

1. Centroid coordinates (location of the center of mass of the ideal cloud).
2. Radii in the wind track, cross track, and vertical directions.

TIMECG

This routine calculates the same parameters of centroid location and cloud radii at time t for the finite size particles in a given size group.

PATH

This routine evaluates the integral of the mass density (mass penetrated) along the sight path between a given transmitter-receiver pair due to each type of particulate material in a given size group at a given time. The quantity evaluated is

$$M_p = \int_0^{D_{TR}} \rho(D)\ dD \quad \mathrm{g\ cm^{-2}} \quad , \tag{45}$$

where

D = distance along sight path from transmitter to receiver (cm)

D_{TR} = total distance from transmitter to receiver (cm)

$\rho(D)$ = mass density at distance D along sight path due to the given particulate material in the given size group ($\mathrm{g\ cm^{-3}}$).

The integration strategy is to begin at the point of closest approach of the sight path to the size group centroid location and numerically integrate forward and backward. The numerical integration uses a Simpson's Rule approximation with a step size of 0.2 of the Gaussian standard deviation of the size group mass density. The integration is continued until the receiver or transmitter is reached or until the mass density becomes negligible. The integration is terminated when the distance from the integration point to the group centroid exceeds five standard deviations. At this point the mass density at the integration point is down at least a factor of $e^{-5^2/2} = 3.7 \times 10^{-6}$ from the density at the cloud centroid.

DEPTH

This routine evaluates the optical depths and transmission along a given sight path at a given time. It calculates the optical depth contribution due to each material in each size group and the sum of all contributions. The quantities evaluated are

$$(\tau_E)_i = (M_p)_i (\mu_E)_i \tag{46}$$

= extinction optical depth contribution due to the particulates in size group i

$(M_P)_i$ = mass penetrated due to particulates in size group i ($g\ cm^{-2}$)

$(\mu_E)_i$ = mass extinction coefficient for particulates in size group i ($cm^2\ g^{-1}$)

$$(\tau_s)_i = (M_P)_i(\mu_s)_i \tag{47}$$

= scattering optical depth contribution

$$(\tau_A)_i = (M_P)_i(\mu_A)_i \tag{48}$$

= absorption optical depth contribution

$$\tau_E = \sum_i (\tau_E)_i \tag{49}$$

= total extinction optical depth due to all size groups

$$\tau_s = \sum_i (\tau_s)_i \tag{50}$$

$$\tau_A = \sum_i (\tau_A)_i \tag{51}$$

$$T = e^{-\tau_E} \tag{52}$$

= transmission (one way).

Routine DEPTH writes out the optical depth contribution results and the total optical depths and transmission. Because the detailed results of the individual optical depth contributions can result in a large amount of output, the printing of these detailed results can be suppressed by an input option.

ADDVEC

This routine and the following vector routines are extremely short and do simple vector operations. This routine adds two three-vectors together:

$$\vec{v} = \vec{v}_1 + \vec{v}_2 = (x_1 + x_2,\ y_1 + y_2,\ z_1 + z_2) \tag{53}$$

where

$\vec{v}_1 = (x_1, y_1, z_1)$ = first three-vector

$\vec{v}_2 = (x_2, y_2, z_2)$ = second three-vector.

SUBVEC

This routine subtracts two three-vectors:

$$\vec{v} = \vec{v}_1 - \vec{v}_2 = (x_1 - x_2,\ y_1 - y_2,\ z_1 - z_2) \quad . \tag{54}$$

MULVEC

This routine multiples a three-vector by a scalar:

$$\vec{v} = s\vec{v}_1 = (sx_1,\ sx_2,\ sx_3) \quad , \tag{55}$$

where

s = scalar .

DOTVEC

This routine forms the scalar (dot) product of two three-vectors:

$$p = \vec{v}_1 \cdot \vec{v}_2 = x_1x_2 + y_1y_2 + z_1z_2 \quad . \tag{56}$$

DSTVEC

This routine evaluates the distance between the endpoints of two three-vectors:

$$D = |\vec{v}_1 - \vec{v}_2| = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2 + (z_1 - z_2)^2} \quad . \tag{57}$$

SECTION 3
INPUT

GENERAL INFORMATION

All input is read by the INPUT subroutine from a logical file unit which has been assigned the number 5. This can be readily changed to meet the requirements of a particular computer installation by changing the value of the variable ITAPE which appears at the beginning of the Executive Routine.

Input is prepared on standard IBM punched cards. Each input card contains a letter, from A to M, punched in column 1 to identify the information contained on that card. The INPUT routine reads the input a card at a time, interprets the identification letter, and assigns the data to the appropriate input variables. Card after card is read until a blank card (a card with no punch in column 1) is read. This signifies that all of the data for this problem have been presented and thus terminates the input sequence and initiates calculation. After all calculations have been completed and the output printed, the Executive Routine returns to the INPUT routine to read the data for the next problem. As many separate problems as desired may be stacked; the data cards for each problem end with a blank card to initiate calculation. Two blank cards in a row indicate the end of the problem sets.

A large number of inputs are required to completely specify a problem. There are 13 different input cards with up to 8 input items on a card. Except for the burst yield, default values are internally supplied for all input values not specified by the user. Before the input data for the first problem are read, the values for all input

variables (except burst yield) are set to the default values. Then the input cards for the first problem are read and all user-specified inputs are substituted for the default values. At the end of the first problem card set, a complete set of input data exists, either all user supplied or a combination of user and default inputs. For the second problem, the code begins with the first problem data set and only the inputs on the second problem data cards are changed from the first problem values. Hence only those cards with information different from the preceding problem need be included on succeeding problems. The only exception is that every problem set must have at least one A card, which contains the burst yield information. Thus a problem set may consist of all 13 different input cards or, at the minimum, consist of a single A card. There are up to 8 input values on a data card.

If any entry is left blank, the code automatically uses the default value for that entry. Hence, when a data card is used on succeeding problems, all entries on that card that are not default values must be supplied even though they may be the same as the preceding problem. If a card is not supplied, the code assumes the values are the same as the preceding case; if a card is supplied, the code assumes that all values on the card are respecified.

DESCRIPTION OF THE INPUT CARDS

Figure 2 shows the input card parameters, and Figure 3 shows the default values. Each input card is read under an A1, E9.0, 7E10.0 format. Thus the data are punched in floating point format in 10-column fields, with the exception that the first field occupies nine columns to make room for the card identification letter in column 1. Note that whole numbers may be punched as integers if the number is right justified within the appropriate field.

Ten bursts are allowed, so there can be up to 10 A and B cards. Similarly 10 transmitter-receiver pairs are allowed, so there can be up to 10 C and D cards. The order of the different cards is

1	10	20	30	40	50	60	70	80
A	$W(1)$ (lb) Total TNT yield of 1st burst	$f_H(1)$ Fraction in hydro yield of 1st burst	$C_T(1)$ Shape factor in track direction of 1st burst	$C_P(1)$ Shape factor in cross track of 1st burst	$C_V(1)$ Shape factor in vertical direction of 1st burst	$X_B(1)$ (m) x-coordinate of 1st burst	$Y_B(1)$ (m) y-coordinate of 1st burst	$Z_B(1)$ (m) z-coordinate of ground surface at 1st burst
B	DOB(2) (m) Depth of burst of 1st burst	$f_{CM}(1)$ Fraction of apparent crater mass lofted	SAC(1) m^3 [lb TNT]$^{-1.111}$ Apparent crater volume scaling factor for 1st burst	$\theta_B(1)$ (deg) Azimuth of 1st shell track (CW from y-axis)				
C	$\nu(1)$ (GHz) Frequency of 1st transmitter receiver	$\lambda(1)$ (μm) Wavelength of 1st transmitter-receiver	$X_T(1)$ (m) X-coordinate of 1st transmitter	$Y_T(1)$ (m) Y-coordinate of 1st transmitter	$Z_T(1)$ (m) Z-coordinate of 1st transmitter	$X_R(1)$ (m) X-coordinate of 1st receiver	$Y_R(1)$ (m) Y-coordinate of 1st receiver	$Z_R(1)$ (m) Z-coordinate of 1st receiver
D	$n_A(1)$ (REAL) Real part of index of refraction for mode A for 1st frequency	$n_A(1)$(IMAG) Imaginary part for mode A for 1st frequency	$n_B(1)$ (REAL) Real part for mode B for 1st frequency	$n_B(1)$(IMAG) Imaginary part mode B for 1st frequency	$n_C(1)$(REAL) Real part for carbon for 1st frequency	$n_C(1)$(IMAG) Imaginary part for carbon for 1st frequency		
E	ρ_G(gm cm^{-3}) Bulk density of soil	ρ_D(gm cm^{-3}) Density of dust grains	f_{H2O} Moisture content fraction of soil mass that is water	ρ_C gm cm^{-3}) Density of carbon particles	L_C Carbon yield fraction(carbon weight divided by total TNT weight)	R_{MAB} Ratio of mode A to mode B mass in lofted cloud	R_{BASE} Ratio of mass in base cloud to mass in main cloud	
F	a_{mA}(μm) Log-normal mean diameter of mode A particles	S_A Log-normal standard deviation parameter mode A particle	a_{minA}(μm) Power law minimum diameter parameter for mode A particles	a_{maxA}(μm) Power law maximum diameter parameter for mode A particles	P_A Power law exponent for mode A particles			
G	a_{mB}(μm) Log normal mean diameter of mode B particles	S_B	a_{minB}(μm)	a_{maxB}(μm)	P_B			
H	a_{mC}(μm) carbon particles	S_C	a_{minC}	a_{maxC}	P_C			
I	P_{SF} Pasquill stability factor 1=A, 2=B, 3=C, 4=D, 5=E, 6=F	λ Entrainment factor for rising cloud	C_D Drag coefficient for rising cloud	ρ_A(gm cm^{-3}) Air density at ground level	H_G(m) Elevation of ground level	T_G(°K) Air temperature at ground level	T_L(°K m^{-1}) Temperature lapse rate	H_I(m) Altitude of inversion layer above ground
J	V_W(m s^{-1}) Mean wind velocity	A_{LTW}(m) Altitude at which mean wind speed is measured	P_{VW} Power law exponent of vertical profile of mean wind-speed	θ_W(DEG) Azimuth of wind velocity vector (measured CW from Y)				
K	$D_G(1)$(m) Maximum diameter of particles in size group 1	$D_G(2)$(m) Maximum diameter in size group 2	$D_G(3)$	$D_G(4)$	$D_G(5)$	$D_G(6)$	$D_G(7)$	$D_G(8)$
L	t(2) (s) Time after burst of 1st calculation	t(2) (s) 2nd calculation time	t(3) (s) 3rd calculation time	t(4)	t(5)	t(6)	t(7)	t(8)
M	P_{RINT} Print control option 0=print details 1=print only summary							

Figure 2. Input card parameters.

1	10	20	30	40	50	60	70	80
A	Must be specified by user	0.5	1	1	1	0	0	0
B	0	0.25	0.03	0				
C	10^5	3	500	50	2	-500	50	2
D	1.66	0.016	1.66	0.016	2	1		
E	1.5	2.5	0.15	1.5	0.3	0.25	0.1	
F	1	2.2						
G	20	2	180	10^4	4			
H	0.5	2						
I	4	1	0.8	0	0	288	$-9.8\text{x}10^{-3}$	1000
J	3	10	0.1	0				
K	5	10	20	30	40	50	60	70
K	80	90	100	105	110	115	120	125
K	130	135	140	145	150	155	160	165
K	170	175	180	185	190	195	200	210
K	220	230	240	250	260	270	280	290
K	300	350	400	450	500	600	750	1000
K	5000	10,000						
L	2	4	6	8	10	12	14	16
L	18	20	22.5	25	27.5	30	32.5	35
L	37.5	40	45	50	55	60	70	80
L	100							
M	0							

Figure 3. Default values for input parameters.

immaterial, but the multiple cards within a given identification card must be in sequence. That is, if there are five A cards, then the five corresponding B cards must be in the same order. The first A card goes with the first B card; the second A card goes with the second B card, etc.

A Card

The A card contains the first part of the burst information. Up to 10 bursts are allowed, so there can be up to 10 A cards. For this version of the code all bursts are assumed to detonate simultaneously at time zero. The first entry is the total TNT yield, or equivalent TNT yield for a non-TNT device, in pounds. This is the one entry which must be specified by the user; no default value is provided. An A card without an entry for the yield will be ignored by the code.

The second entry is f_H, the fraction of the total yield which appears as hydrodynamic energy. f_H is used in the determination of the initial ideal spherical cloud radius,

$$R_I = 1.54\left(Wf_H \frac{\rho_o}{\rho}\right)^{1/3} \quad \mathrm{m} \quad , \tag{58}$$

where

W = total munition yield (lb TNT)
ρ_o = sea level air density (g cm^{-3})
ρ = air density at blast site (g cm^{-3}).

The third, fourth, and fifth entries are the shape factors for the real initial dust cloud. A static blast will generally produce an initial cloud that is roughly spherical ($C_T = C_P = C_V = 1$). But a live munition impacts the ground with a large velocity and can produce dust clouds that are elongated in the shell track direction. The radii of the initial real dust cloud in the shell track, cross track, and vertical directions are taken as the product of these shape factors and the ideal spherical cloud radius of Equation 58:

$$R_T = C_T R_I \quad m \tag{59a}$$

$$R_P = C_P R_I \tag{59b}$$

$$R_V = C_V R_I \quad . \tag{59c}$$

The sixth, seventh, and eighth entries are the coordinates of the ground surface at the burst. Note that the z coordinate is the coordinate of the ground surface and not that of the burst itself. A surface burst and a buried burst have the same z coordinate.

B Card

The B card contains the rest of the burst information. The first B card goes with the first A card, the second B card with the second A card, etc. If there are more A cards than B cards, the code automatically fills the missing B inputs with default values. If there are more B cards than A cards, the code simply ignores the excess B cards.

The first B entry is the depth of burst. This is the distance the munition center of mass is below the ground surface at detonation. A munition that detonates above the ground would have a negative value for depth of burst. Currently this variable is not used in the code. For some soils the apparent crater volume scaling factor is a smooth function of the depth of burst. For these soils the scaling factor could be internally calculated rather than being input.

The second entry is the fraction of the apparent crater mass that is lofted into the dust cloud. A crater is left in the soil after a munition explosion. The volume of this visible crater (that part below the original ground level) is the apparent crater volume. The apparent crater mass is the mass of the soil that was in the apparent crater volume. Part of the mass is lofted into the dust cloud, part is thrown out to the sides, and part is piled up on the crater lip.

The third entry is the apparent crater volume scaling factor. The volume of the apparent crater is calculated from the scaling relation,

$$V_A = S_{AC}W^{1.111} \quad m^3 \quad , \tag{60}$$

where

V_A = volume of apparent crater (m^3)
S_{AC} = apparent crater volume scaling factor (m^3 (lb TNT)$^{-1.111}$)
W = total munition yield (lb TNT).

The scaling factor depends on the type of soil, type of munition, and depth of burst. Both the half-buried static charges of the Dugway series of tests and the static charges of DIRT 1 had a scaling factor of about 0.03.

The fourth entry is the azimuth of the munition shell track. Azimuths are measured clockwise (toward the x axis) in degrees from the y axis. The azimuth is used in conjunction with the shape factors to define the initial main cloud shape and orientation. The shell azimuth input is not required for those bursts which are symmetric about the vertical axis (ie, for bursts with $C_T = C_P$).

C Card

The C card contains the transmitter-receiver information. A maximum of 10 transmitter-receiver pairs are permitted, so there can be up to 10 C cards.

The first and second entries are the frequency in GHz and the wavelength in microns of the transmitter-receiver pair. Only one of these two inputs is required; the other input is left blank. The input choice is for the user's convenience. Users working with millimeter waves generally prefer GHz frequencies, while infrared users prefer micron wavelengths.

The third through eighth entries are the coordinates of the transmitter and receiver. The z coordinate is the actual z coordinate of the transmitter or receiver (unlike the burst coordinate, where the z coordinate is the coordinate of the ground surface). The transmitter-receiver coordinates define the sight path, which is the straight line path between the transmitter and receiver.

D Card

The D card contains the complex index of refraction information. There should be one D card for each C card. If there are more C cards than D cards, the code automatically fills the missing D inputs with default values. If there are more D cards than C cards, the code simply ignores the excess D cards.

The complex index of refraction at the transmitter-receiver frequency is assumed to be

$$n = n_R - in_I \quad , \tag{61}$$

where

n = complex index of refraction
n_R = real part of the complex index of refraction
n_I = imaginary part of the complex index of refraction
$i = \sqrt{-1}$.

Hence all input entries are positive.

The first and second entries are for the mode A dust particles, the third and fourth are for mode B dust particles, and the fifth and sixth are for the carbon particles. Note that these indices are for the airborne particles. The indices of *in situ* soil generally differ from the indices of airborne dust grains. This difference is due to the air and water in the soil.

E Card

The E card carries various soil, dust, and carbon parameters and mass partitions. There is only one E card.

The first entry is the bulk density of the *in situ* soil in g cm^{-3}. This variable is used along with the calculated apparent crater volume to calculate the total mass of soil that was in the apparent crater. Typical values for soil density are about 1.5 g cm^{-3} for loose soil and about 2.5 g cm^{-3} for rock. *In situ* soil is assumed to consist of dust grains, air, and water.

The second entry is the density in g cm^{-3} of the airborne dust grains. For soils this grain density is larger than the soil density; a typical grain density value is 2.5 g cm^{-3}. Nonporous rock can have the same value for the *in situ* soil density and the grain density.

The third entry is the soil moisture fraction. This is defined as the mass of water in the soil divided by the mass of the soil (including the water). The mass of the solid dust grains is taken as the mass of the soil minus the mass of the water.

The fourth entry is the density of the carbon particulates in g cm^{-3}. The default value is 1.5 g cm^{-3}.

The fifth entry is the carbon yield fraction. One of the combustion products from the burning of the explosive is carbon. The carbon yield fraction is defined as the mass of the carbon produced divided by the mass of the explosive. A typical value for TNT is 0.3.

The sixth entry is the ratio of mode A to mode B dust mass in the lofted cloud. We allow two types of dust in the cloud, and this entry specifies the relative importance of the two types. If a user wishes to have only one kind of dust, then this entry should be set to an insignificant number such as 10^{-3}. Remember that if this entry is left blank or set to zero, the code will automatically insert the default value, which is 0.25.

The seventh entry is the ratio of the mass in the base cloud to the mass in the main cloud. Although the base cloud generally has only a small fraction of the mass of the main cloud, the base cloud can have a large effect on sight paths very near the ground since it is nonrising. Typical estimates of this ratio are in the range 0.05 to 0.1; we take 0.1 as the default value.

F Card

The F card specifies the size distribution parameters for the mode A dust particles. There is only one F card. At present three types of size probability distributions are allowed: log normal, power law,

or hybrid. The hybrid distribution consists of a log normal distribution for particles with diameters from zero to a_{min}; this is then joined to a power law distribution for particles with diameters from a_{min} to a_{max}. To choose a log normal distribution, values are entered for entries one and two. To choose a power law distribution, values are entered for entries three, four, and five. To choose a hybrid distribution, values must be given for all five entries.

The log normal probability distribution is

$$P_{LN}(a) = \frac{\exp\left\{-\frac{1}{2}\left[\frac{\ln\frac{a}{a_m}}{\ln S}\right]^2\right\}}{\sqrt{2\pi}\, a \ln S} \qquad 0 \leq a \leq \infty \tag{62}$$

where

a = particle diameter (microns)

$P_{LN}(a)\, da$ = fraction of the number of dust particles with diameters between a and $a + da$

a_m = mean particle diameter (microns)

S = standard deviation parameter.

The power law probability distribution is

$$P_p(a) = \frac{(p - 1)a^{-p}}{a_{min}^{-(p-1)} - a_{max}^{-(p-1)}} \qquad a_{min} \leq a \leq a_{max} \tag{63}$$

where

p = power law exponent

a_{min} = minimum particle diameter in the power law size distribution (microns)

a_{max} = maximum particle diameter in the distribution (microns).

The hybrid distribution is

$$P_H(a) = \begin{cases} C_1 P_{LN}(a) & 0 \leq a \leq a_{min} \\ C_2 P_p(a) & a_{min} \leq a \leq a_{max} \end{cases} \tag{64}$$

where C_1 and C_2 are normalization constants.

The first entry on the F card is the mean diameter in microns of the log normal probability distribution. The second entry is the standard deviation parameter of the log normal distribution.

The third entry is the minimum diameter in microns of the power law distribution. The fourth entry is the maximum diameter in microns of the power law distribution. The fifth entry is the power law exponent of the power law distribution.

G Card

The G card specifies the size distribution parameters for the mode B dust particles. There is only one G card. The G card entries have the same definitions as the F card entries.

H Card

The H card specifies the size distribution parameters for the carbon particles. There is only one H card. The H card entries have the same definitions as the F and G card entries.

I Card

The I card is the first of two cards specifying the atmospheric parameters and the rising (main) cloud model parameters. There is only one I card.

The first entry is the atmospheric Pasquill stability factor, entered as a digit with the correspondence 1 = A, 2 = B, 3 = C, 4 = D, 5 = E, 6 = F. The default value is 4 (D), the neutral stability.

The second entry is the entrainment factor for the buoyant rising cloud model. Normally this entry is left blank and the code uses the default value of 1.

The third entry is the drag coefficient for the buoyant rising cloud model. Normally this entry is also left blank, thereby specifying the default value of 0.8.

The fourth entry is the air density in g cm^{-3} at ground level. If this entry is left blank, the code assumes the atmosphere is the U.S. Standard atmosphere and calculates the ground level density as

$$\rho_A = \rho_{A0}\, e^{-\frac{H_G}{8400}} \quad g\ cm^{-3} \quad , \tag{65}$$

where

ρ_A = air density at ground level (g cm^{-3})

ρ_{A0} = U.S. Standard Atmosphere air density at mean sea level
= 1.225×10^{-3} g cm^{-3}

H_G = elevation above mean sea level of the ground level (m).

The fifth entry is the elevation of the ground level above mean sea level in meters. This entry is only used to calculate the air density at ground level. Thus if the user specifies the fourth entry, ρ_A, then this entry is not used in the code.

The sixth and seventh entries are the air temperature at ground level and the temperature lapse rate in kelvins and kelvins per meter, respectively. At present these entries are not used in the code and need not be specified. In the future we expect these variables to enter into the models for main cloud stabilization and buoyant-atmospheric diffusion crossover. Anticipating the future model development, we have reserved these input slots.

The eighth entry is the altitude of the air temperature inversion layer in meters above ground level. Inversion layers are effective barriers for rising dust clouds. The code assumes the main dust cloud cannot rise above the inversion layer. Hence at present the temperature inversion layer is the stabilization altitude for the main dust cloud.

J Card

The J card is the second of the two cards specifying the atmospheric parameters. There is only one J card.

The first entry is the mean wind velocity in meters per second. The second entry is the reference altitude in meters at which the mean wind velocity is measured. The third entry is the power law exponent of the vertical profile of the mean wind velocity. The wind speed as a function of altitude is assumed to be

$$v_M(Z) = v_M(Z_R)\left(\frac{Z}{Z_R}\right)^{P_M} \quad \text{m s}^{-1} \quad , \tag{66}$$

where

$v_M(Z)$ = mean wind velocity at altitude Z (m s^{-1})
$v_M(Z_R)$ = mean wind velocity at reference altitude Z_R (m s^{-1})
P_M = power law exponent.

The fourth entry is the azimuth of the mean wind velocity vector in degrees, measured clockwise from the y axis.

K Card

The K card contains the particle size group information. A maximum of 50 size groups are permitted, so there can be up to seven K cards. The entries are the maximum diameters in microns of the particles in the size groups. The diameters are entered in ascending order. The first size group includes particles of diameter zero up to the diameter of the first entry. The second size group includes particles with diameters from the first entry to the second entry.

A given size group includes all particles of all materials which have diameters within the specified diameter ranges. Thus a particular size group can have one, two, or three types of the different material particles in it, depending upon the size distributions of the three materials.

L Card

The L card contains the calculation times in seconds. All bursts are assumed to be detonated at time zero. A maximum of 25 calculation times are allowed, so there can be up to four L cards (the last card

having only one entry). The input times must be positive and arranged in ascending order.

M Card

The M card contains the print control option. The code computes the propagation along each sight path by summing the effects from each particle size group for each material for each burst. Unless suppressed, the code will automatically print out the details of each contributing effect. This detailed printing can produce a considerable amount of output which may not be of interest to the user. A 1 entered in column 10 of card M will suppress the printing of the details. Since the default value of the print control option is zero, the code will print the detailed output if card M is omitted. Naturally the summary output is printed in all cases.

SECTION 4
SAMPLE PROBLEM

Figure 4 shows the input data cards for the sample problem. We have a single 360-lb TNT burst at the origin. There is a single transmitter-receiver pair using a wavelength of 10.35 microns. The data chosen correspond to test event B8 of the DIRT-1 series of tests at White Sands Missile Range, New Mexico (Reference 6). The actual test consisted of three 120-lb TNT charges in a line with 15 meters spacing between charges. The three individual dust clouds rapidly (in less than a second) merged to form one large dust cloud. We simulate this one large dust cloud in the code by a single 360-lb burst and by increasing the entrainment factor (second entry, card I) to a value of 2.

Figure 5 shows the output generated by the code, which first writes out the input data. Next the code calculates the propagation constants for each significant size group for each material, assuming no mixing of particles between size groups. After the unmixed data are printed out, the propagation constants are recomputed assuming mixing of the size groups; the mixed data are then printed. Next the initial (t = 0+) parameters of the main cloud are computed and printed out. Then the initial dust and carbon masses lofted into the main and base clouds are written out. This completes the preliminary calculations. For each calculation time the propagation along each sight path is computed and printed out, first the detailed results (unless suppressed by the print control option) and then the summary results.

1	10	20	30	40	50	60	70	80
A	360	0.8	1*	1	1	0	0	0
B	0.1	0.50	0.03	0				
C		10.35	1.2	-1000	1.7	1.2	1000	1.7
D	1.65	0.14	1.65	0.14	3.4	2.8		
E	1.6	2.5	0.08	1.5	0.3	0.25	0.1	
F	3.1	2.34						
G	7.1	2.65						
I	4	2	0.8		1260	288	$-9.8\mathrm{x}10^{-3}$	1000
J	1.8	2	0.19	26				
K	20	40	60	80	100	120	140	160
K	180	200	225	250	275	300	500	700
K	1000	2000						
L	60	80	100	120	140			

*Note that all entries which are default values could have been left blank

Figure 4. Input cards for sample problem.

ASL MUNITION DUST CLOUD MODEL

INPUT DATA FOR PROBLEM NUMBER 1

MUNITION AND CRATER PARAMETERS

BURST	YIELD (LB TNT)	HYDRO FRACTION	INITIAL SHAPE FACTORS ALONG TRACK	CROSS TRACK	VERTICAL	BURST POINT COORDINATES X COORD, (METERS)	Y COORD, (METERS)	Z COORD, (METERS)	DEPTH OF BURST (METERS)	LOFTED MASS FRACTION	LOADING FACTOR (M3/LB TNT1.1)	SHELL TRACK AZIMUTH (DEG)
1	360.0	0.8	1.0	1.0	1.0	0.	0.	0.	0.1	0.50	3.00E-02	0.

BULK DENSITY OF SOIL = 1.6 GM/CM3
SOIL MOISTURE FRACTION = 0.08

SIZE PROBABILITY DISTRIBUTION PARAMETERS

MATERIAL	DENSITY (GM/CM3)	MEAN DIAMETER (MICRONS)	STANDARD DEVIATION PARAMETER	MINIMUM DIAMETER (MICRONS)	MAXIMUM DIAMETER (MICRONS)	POWER LAW EXPONENT
DUST - A	2.50	3.10	2.3	0.	0.	0.
DUST - B	2.50	7.10	2.7	0.	0.	0.
CARBON	1.50	0.50	2.0	0.	0.	0.

CARBON YIELD FRACTION = 0.30
RATIO MODE A TO MODE B MASS = 0.25
RATIO BASE TO MAIN CLOUD MASS = 0.10

MAXIMUM DIAMETERS OF PARTICLES IN EACH SIZE GROUP

SIZE GROUP NUMBER	1	2	3	4	5	6	7	8	9	10
MAXIMUM DIAMETER (MICRONS)	20.0	40.0	60.0	80.0	100.0	120.0	140.0	160.0	180.0	200.0
	11	12	13	14	15	16	17	18		
	2:5.0	250.0	275.0	300.0	500.0	700.0	1000.0	2000.0		

Figure 5. ASL-DUST output for sample problem.

INPUT DATA FOR PROBLEM NUMBER 1 (CONTINUED)

TRANSMITTER - RECEIVER PARAMETERS

PAIR NUMBER	FREQUENCY (GHZ)	WAVELENGTH (MICRONS)	TRANSMITTER COORDINATES X OORD. (METERS)	TRANSMITTER COORDINATES Y COORD. (METERS)	TRANSMITTER COORDINATES Z COORD. (METERS)	RECEIVER COORDINATES X COORD. (METERS)	RECEIVER COORDINATES Y COORD. (METERS)	RECEIVER COORDINATES Z COORD. (METERS)
1	2.90E 04	10.4	1.2	-1000.0	1.7	1.2	1000.0	1.7

INDICIES OF REFRACTION

PAIR NUMBER	FREQUENCY (GHZ)	WAVELENGTH (MICRONS)	DUST - MODE A REAL PART	DUST - MODE A IMAG PART	DUST - MODE B REAL PART	DUST - MODE B IMAG PART	CARBON REAL PART	CARBON IMAG PART
1	2.90E 04	10.4	1.65	1.40E-01	1.65	1.40E-01	3.40	2.80E 00

ATMOSPHERIC PARAMETERS

PASQUILL STABILITY FACTOR	CLOUD ALPHA ENTRAINMENT FACTOR	CLOUD DRAG COEFFICIENT	AIR DENSITY AT GROUND (GM/CM3)	GROUND ELEVATION (METERS)	GROUND AIR TEMPERATURE (DEG K)	TEMPERATURE LAPSE RATE (DEG K/ M)	INVERSION LAYER ALTITUDE (METERS)
D	2.0	0.8	1.05E-03	1260.0	288.0	-9.8E-03	1000.0

MEAN WIND VELOCITY (M/S)	WIND REFERENCE ALTITUDE (METERS)	WIND VERTICAL PROFILE POWER LAW EXPONENT	WIND AZIMUTH (DEG)
1.8	2.0	0.19	26.0

ASL MUNITION DUST CLOUD MODEL

PROPAGATION CONSTANTS FOR PROBLEM NUMBER 1
(SIZE DISTRIBUTION ONLY, NO FRACTIONIZATION)

DUST PARTICLES - MODE A

WAVELENGTH = 10.4 MICRONS (FREQUENCY = 2.90E 04 GHZ)

SIZE GROUP	MAXIMUM DIAMETER (MICRONS)	NUMBER OF PARTICLES PER GRAM IN GROUP	NUMBER FRACTION (NUMBER IN GROUP /TOTAL NUMBER)	MASS FRACTION (MASS IN GROUP /TOTAL MASS)	GROUP MASS COEFFICIENTS (FIRST LINE, CM2/GM) AVERAGE CROSS SECTIONS (SECOND LINE, CM2/PARTICLE) EXTINCTION	ABSORPTION	SCATTERING	BACKSCATTER
1	20.0	2.714E 09	9.858E-01	3.604E-01	1.427E 03 5.259E-07	5.832E 02 2.149E-07	8.438E 02 3.109E-07	7.562E 01 2.787E-08
2	40.0	4.030F 07	1.284E-02	3.161E-01	5.197E 02 1.290E-05	2.669E 02 6.624E-06	2.528E 02 6.273E-06	4.021E 00 9.978E-08
3	60.0	7.129E 06	1.068E-03	1.486E-01	2.880E 02 4.040E-05	1.401E 02 1.966E-05	1.478E 02 2.074E-05	7.347E 00 1.031E-06
4	80.0	2.432E 06	1.801E-04	7.347E-02	1.969E 02 8.098E-05	9.342E 01 3.841E-05	1.035E 02 4.257E-05	5.519E 00 2.269E-06
5	100.0	1.110E 06	4.384E-05	3.917E-02	1.493E 02 1.345E-04	6.972E 01 6.280E-05	7.956E 01 7.167E-05	4.237E 00 3.817E-06
6	120.0	5.981E 05	1.342E-05	2.226E-02	1.201E 02 2.008E-04	5.550E 01 9.281E-05	6.459E 01 1.080E-04	3.449E 00 5.767E-06
7	140.0	3.587E 05	4.823E-06	1.334E-02	1.006E 02 2.803E-04	4.612E 01 1.286E-04	5.443E 01 1.517E-04	2.914E 00 8.124E-06
8	160.0	2.320E 05	1.950E-06	8.336E-03	8.644E 01 3.726E-04	3.943E 01 1.700E-04	4.702E 01 2.027E-04	2.525E 00 1.088E-05
9	180.0	1.586E 05	8.644E-07	5.405E-03	7.579E 01 4.777E-04	3.441E 01 2.169E-04	4.138E 01 2.608E-04	2.224E 00 1.402E-05
10	200.0	1.133E 05	4.123E-07	3.610E-03	6.746E 01 5.956E-04	3.052E 01 2.695E-04	3.694E 01 3.261E-04	1.989E 00 1.756E-05
11	225.0	8.155E 04	2.439E-07	2.967E-03	6.012E 01 7.372E-04	2.712E 01 3.325E-04	3.300E 01 4.047E-04	1.780E 00 2.182E-05
12	250.0	5.791E 04	1.118E-07	1.914E-03	5.354E 01 9.245E-04	2.408E 01 4.158E-04	2.946E 01 5.087E-04	1.591E 00 2.748E-05
13	275.0	4.278E 04	5.486E-08	1.272E-03	4.825E 01 1.128E-03	2.165E 01 5.061E-04	2.660E 01 6.218E-04	1.439E 00 3.364E-05

PROPAGATION CONSTANTS FOR PROBLEM NUMBER 1 (CONTINUED)

SIZE GROUP	MAXIMUM DIAMETER (MICRONS)	NUMBER OF PARTICLES PER GRAM IN GROUP	NUMBER FRACTION (NUMBER IN GROUP /TOTAL NUMBER)	MASS FRACTION (MASS IN GROUP /TOTAL MASS)	GROUP MASS COEFFICIENTS (FIRST LINE, CM2/GM) AVERAGE CROSS SECTIONS (SECOND LINE, CM2/PARTICLE) EXTINCTION	ABSORPTION	SCATTERING	BACKSCATTER
14	300.0	3.250E 04	2.841E-08	8.671E-04	4.391E 01	1.967E 01	2.425E 01	1.313E 00
					1.351E-03	6.052E-04	7.461E-04	4.042E-05
15	500.0	1.772E 04	3.644E-08	2.040E-03	3.511E 01	1.569E 01	1.942E 01	1.054E 00
					1.982E-03	8.857E-04	1.096E-03	5.946E-05
16	700.0	4.294E 03	1.029E-09	2.377E-04	2.205E 01	9.848E 00	1.220E 01	6.622E-01
					5.134E-03	2.293E-03	2.841E-03	1.542E-04
17	1000.0	1.564E 03	8.603E-11	5.456E-05	1.573E 01	7.027E 00	8.705E 00	4.725E-01
					1.006E-02	4.493E-03	5.566E-03	3.021E-04
18	2000.0	4.989E 02	5.418E-12	1.077E-05	1.064E 01	4.753E 00	5.889E 00	3.196E-01
					2.133E-02	9.528E-03	1.180E-02	6.407E-04
ENTIRE DISTRIBUTION					7.475E 02	3.277E 02	4.198E 02	3.035E 01

ASL MUNITION DUST CLOUD MODEL

PROPAGATION CONSTANTS FOR PROBLEM NUMBER 1
(SIZE DISTRIBUTION ONLY, NO FRACTIONIZATION)

DUST PARTICLES - MODE 8

WAVELENGTH = 10.4 MICRONS (FREQUENCY = 2.90[illegible] 04 GHZ)

SIZE GROUP	MAXIMUM DIAMETER (MICRONS)	NUMBER OF PARTICLES PER GRAM IN GROUP	NUMBER FRACTION (NUMBER IN GROUP /TOTAL NUMBER)	MASS FRACTION (MASS IN GROUP /TOTAL MASS)	GROUP MASS COEFFICIENTS (FIRST LINE, CM2/GM) AVERAGE CROSS SECTIONS (SECOND LINE, CM2/PARTICLE) EXTINCTION	ABSORPTION	SCATTERING	BACKSCATTER
1	20.0	8.111E 08	8.560E-01	3.137E-02	1.284E 03	5.468E 02	7.376E 02	1.843E 01
					1.584E-06	6.742E-07	9.094E-07	2.273E-08
2	40.0	3.359E 07	1.059E-01	9.375E-02	4.875E 02	2.484E 02	2.392E 02	3.867E 00
					1.452E-05	7.395E-06	7.121E-06	1.151E-07
3	60.0	6.640E 06	2.378E-02	1.048E-01	2.808E 02	1.364E 02	1.444E 02	7.181E 00
					4.229E-05	2.054E-05	2.175E-05	1.082E-06
4	80.0	2.340E 06	7.789E-03	9.894E-02	1.944E 02	9.212E 01	1.023E 02	5.438E 00
					8.307E-05	3.937E-05	4.370E-05	2.324E-06
5	100.0	1.083E 06	3.152E-03	8.650E-02	1.481E 02	6.915E 01	7.897E 01	4.206E 00
					1.367E-04	6.384E-05	7.290E-05	3.883E-06
6	120.0	5.878E 05	1.464E-03	7.403E-02	1.195E 02	5.521E 01	6.428E 01	3.433E 00
					2.033E-04	9.392E-05	1.093E-04	5.840E-06
7	140.0	3.541E 05	7.497E-04	6.298E-02	1.002E 02	4.594E 01	5.424E 01	2.904E 00
					2.829E-04	1.297E-04	1.532E-04	8.202E-06
8	160.0	2.296E 05	4.132E-04	5.349E-02	8.620E 01	3.931E 01	4.689E 01	2.518E 00
					3.754E-04	1.712E-04	2.042E-04	1.097E-05
9	180.0	1.573E 05	2.413E-04	4.559E-02	7.562E 01	3.433E 01	4.128E 01	2.220E 00
					4.807E-04	2.183E-04	2.624E-04	1.411E-05
10	200.0	1.125E 05	1.476E-04	3.900E-02	6.734E 01	3.047E 01	3.687E 01	1.985E 00
					5.988E-04	2.709E-04	3.279E-04	1.765E-05
11	225.0	8.061E 04	1.116E-04	4.115E-02	5.998E 01	2.705E 01	3.293E 01	1.776E 00
					7.440E-04	3.356E-04	4.085E-04	2.203E-05
12	250.0	5.762E 04	6.648E-05	3.430E-02	5.344E 01	2.403E 01	2.940E 01	1.589E 00
					9.274E-04	4.171E-04	5.103E-04	2.757E-05
13	275.0	4.261E 04	4.126E-05	2.879E-02	4.818E 01	2.162E 01	2.656E 01	1.437E 00
					1.131E-03	5.073E-04	6.233E-04	3.373E-05

PROPAGATION CONSTANTS FOR PROBLEM NUMBER 1 (CONTINUED)

SIZE GROUP	MAXIMUM DIAMETER (MICRONS)	NUMBER OF PARTICLES PER GRAM IN GROUP	NUMBER FRACTION (NUMBER IN GROUP /TOTAL NUMBER)	MASS FRACTION (MASS IN GROUP /TOTAL MASS)	GROUP MASS COEFFICIENTS (FIRST LINE, CM2/GM) AVERAGE CROSS SECTIONS (SECOND LINE, CM2/PARTICLE) EXTINCTION	ABSORPTION	SCATTERING	BACKSCATTER
14	300.0	3.239E 04	2.651E-05	2.433E-02	4.385E 01	1.964E 01	2.421E 01	1.312E 00
					1.354E-03	6.063E-04	7.475E-04	4.050E-05
15	500.0	1.557E 04	5.484E-05	1.047E-01	3.340E 01	1.492E 01	1.847E 01	1.002E 00
					2.145E-03	9.586E-04	1.187E-03	6.439E-05
16	700.0	4.020E 03	5.109E-06	3.771E-02	2.157E 01	9.635E 00	1.194E 01	6.479E-01
					5.356E-03	2.392E-03	2.964E-03	1.609E-04
17	1000.0	1.456E 03	1.043E-06	2.130E-02	1.535E 01	6.654E 00	8.491E 00	4.609E-01
					1.054E-02	4.708E-03	5.833E-03	3.166E-04
18	2000.0	4.123E 02	1.881E-07	1.356E-02	9.887E 00	4.416E 00	5.471E 00	2.970E-01
					2.398E-02	1.071E-02	1.327E-02	7.203E-04
ENTIRE DISTRIBUTION					1.853E 02	8.706E 01	9.824E 01	3.701E 00

ASL MUNITION DUST CLOUD MODEL

PROPAGATION CONSTANTS FOR PROBLEM NUMBER 1
(SIZE DISTRIBUTION ONLY, NO FRACTIONIZATION)

CARBON PARTICLES

WAVELENGTH = 10.4 MICRONS (FREQUENCY = 2.90E 04 GHZ)

SIZE GROUP	MAXIMUM DIAMETER (MICRONS)	NUMBER OF PARTICLES PER GRAM IN GROUP	NUMBER FRACTION (NUMBER IN GROUP /TOTAL NUMBER)	MASS FRACTION (MASS IN GROUP /TOTAL MASS)	GROUP MASS COEFFICIENTS (FIRST LINE, CM2/GM) AVERAGE CROSS SECTIONS (SECOND LINE, CM2/PARTICLE) EXTINCTION	ABSORPTION	SCATTERING	BACKSCATTER
1	20.0	1.173E 12	1.000E 00	9.994E-01	5.142E 03	3.238E 03	1.904E 03	2.285E 03
					4.384E-09	2.761E-09	1.623E-09	1.948E-09
2	40.0	1.031E 08	5.116E-08	5.815E-04	1.059E 03	3.327E 02	7.266E 02	1.960E 02
					1.027E-05	3.226E-06	7.045E-06	1.900E-06
3	60.0	1.432E 07	1.266E-10	1.037E-05	5.212E 02	1.545E 02	3.667E 02	1.025E 02
					3.641E-05	1.079E-05	2.561E-05	7.158E-06
4	80.0	4.500E 06	2.354E-12	6.132E-07	3.455E 02	9.970E 01	2.458E 02	7.263E 01
					7.679E-05	2.216E-05	5.463E-05	1.614E-05
ENTIRE DISTRIBUTION					5.140E 03	3.237E 03	1.903E 03	2.284E 03

ASL MUNITION DUST CLOUD MODEL

PROPAGATION CONSTANTS FOR PROBLEM NUMBER 1
(FRACTIONIZATION EFFECTS INCLUDED)

DUST PARTICLES = MODE A

WAVELENGTH = 10.6 MICRONS (FREQUENCY = 2.90E 04 GHZ)

SIZE GROUP	MAXIMUM DIAMETER (MICRONS)	MASS FRACTION (MASS IN GROUP /TOTAL MASS)	GROUP MASS COEFFICIENTS (CM2/GM) EXTINCTION	ABSORPTION	SCATTERING	BACKSCATTER
1	20.0	1.802E-01	1.427E 03	5.832E 02	8.438E 02	7.562E 01
2	40.0	2.471E-01	8.467E 02	3.809E 02	4.658E 02	2.982E 01
3	60.0	1.887E-01	7.554E 02	3.310E 02	4.244E 02	3.113E 01
4	80.0	1.205E-01	7.286E 02	3.172E 02	4.114E 02	3.059E 01
5	100.0	8.056E-02	7.170E 02	3.115E 02	4.055E 02	3.028E 01
6	120.0	5.279E-02	[illegible]	3.085E 02	4.024E 02	3.011E 01
7	140.0	3.533E-02	7.072E 02	3.067E 02	4.005E 02	3.001E 01
8	160.0	2.417E-02	7.047E 02	3.055E 02	3.992E 02	2.994E 01
9	180.0	1.689E-02	7.030E 02	3.047E 02	3.983E 02	2.990E 01
10	200.0	1.200E-02	7.018E 02	3.042E 02	3.976E 02	2.986E 01
11	225.0	1.040E-02	7.007E 02	3.037E 02	3.971E 02	2.983E 01
12	250.0	7.195E-03	6.999E 02	3.033E 02	3.966E 02	2.981E 01
13	275.0	5.053E-03	6.992E 02	3.030E 02	3.962E 02	2.979E 01
14	300.0	3.616E-03	6.987E 02	3.027E 02	3.960E 02	2.977E 01
15	500.0	8.884E-03	6.977E 02	3.023E 02	3.954E 02	2.974E 01
16	700.0	1.835E-03	6.968E 02	3.019E 02	3.949E 02	2.972E 01
17	1000.0	5.205E-04	6.965E 02	3.017E 02	3.947E 02	2.971E 01
18	2000.0	1.354E-04	6.690E 02	2.898E 02	3.792E 02	2.853E 01

ASL MUNITION DUST CLOUD MODEL

PROPAGATION CONSTANTS FOR PROBLEM NUMBER 1
(FRACTIONIZATION EFFECTS INCLUDED)

DUST PARTICLES - MODE 8

WAVELENGTH = 10.4 MICRONS (FREQUENCY = 2.90E 04 GHZ)

SIZE GROUP	MAXIMUM DIAMETER (MICRONS)	MASS FRACTION (MASS IN GROUP /TOTAL MASS)	GROUP MASS COEFFICIENTS (CM2/GM) EXTINCTION	ABSORPTION	SCATTERING	BACKSCATTER
1	20.0	1.569E-02	1.284E 03	5.468E 02	7.376E 02	1.843E 01
2	40.0	4.840E-02	5.126E 02	2.578E 02	2.548E 02	4.325E 00
3	60.0	6.066E-02	3.312E 02	1.595E 02	1.717E 02	7.232E 00
4	80.0	6.326E-02	2.636E 02	1.249E 02	1.387E 02	5.869E 00
5	100.0	6.172E-02	2.312E 02	1.088E 02	1.224E 02	5.006E 00
6	120.0	5.833E-02	2.130E 02	9.995E 01	1.131E 02	4.515E 00
7	140.0	5.419E-02	2.018E 02	9.457E 01	1.073E 02	4.208E 00
8	160.0	4.985E-02	1.943E 02	9.101E 01	1.033E 02	4.001E 00
9	180.0	4.560E-02	1.890E 02	8.852E 01	1.005E 02	3.852E 00
10	200.0	4.160E-02	1.852E 02	8.671E 01	9.845E 01	3.742E 00
11	225.0	4.651E-02	1.819E 02	8.520E 01	9.671E 01	3.649E 00
12	250.0	4.143E-02	1.792E 02	8.395E 01	9.525E 01	3.572E 00
13	275.0	3.692E-02	1.772E 02	8.301E 01	9.414E 01	3.513E 00
14	300.0	3.294E-02	1.756E 02	8.228E 01	9.328E 01	3.467E 00
15	500.0	1.489E-01	1.719E 02	8.062E 01	9.126E 01	3.358E 00
16	700.0	8.084E-02	1.691E 02	7.939E 01	8.973E 01	3.275E 00
17	1000.0	5.719E-02	1.580E 02	7.887E 01	8.909E 01	3.240E 00
10	2000.0	5.385E-02	1.474E 02	6.918E 01	7.818E 01	2.849E 00

ASL MUNITION DUST CLOUD MODEL

PROPAGATION CONSTANTS FOR PROBLEM NUMBER 1
(FRACTIONIZATION EFFECTS INCLUDED)

CARBON PARTICLES

WAVELENGTH = 10.0 MICRONS (FREQUENCY = 2.90E 04 GHZ)

SIZE GROUP	MAXIMUM DIAMETER (MICRONS)	MASS FRACTION (MASS IN GROUP /TOTAL MASS)	GROUP MASS COEFFICIENTS (CM2/GM) EXTINCTION	ABSORPTION	SCATTERING	BACKSCATTER
1	20.0	4.997E-01	5.142E 03	3.238E 03	1.904E 03	2.285E 03
2	40.0	4.907E-01	5.140E 03	3.237E 03	1.903E 03	2.284E 03
3	60.0	9.025E-03	5.139E 03	3.237E 03	1.903E 03	2.284E 03
4	80.0	5.393E-04	5.136E 03	3.235E 03	1.902E 03	2.282E 03

GEOMETRIC PARAMETERS OF THE INITIAL DUST CLOUDS

BURST NUMBER	EQUIVALENT SPHERICAL CLOUD RADIUS (METERS)	RADIUS IN SHELL TRACK DIRECTION (METERS)	RADIUS IN SHELL CROSS TRACK DIRECTION(METERS)	RADIUS IN VERTICAL DIRECTION (METERS)	RADIUS IN WIND TRACK DIRECTION (METERS)	RADIUS IN WIND CROSS TRACK DIRECTION(METERS)	SPHERICAL CLOUD RISE CONSTANT	SPHERICAL CLOUD DIFFUSION COEFFICIENT (METERS2/S)	DUST CLOUD VERTICAL DIFFUSION COEFFICIENT (METERS2/S)
1	10.7	10.7	10.7	10.7	10.7	10.7	3.23	21.91	18.54

INITIAL DUST AND CARBON MASSES LOFTED (GM)

BURST NUMBER	MAIN CLOUD			BASE CLOUD			TOTAL(MAIN + BASE CLOUD)			
	DUST-MODE A	DUST-MODE B	CARBON	DUST-MODE A	DUST-MODE B	CARBON	DUST-MODE A	DUST-MODE B	CARBON	SUM(A+B+C)
1	4.34E 06	1.74E 07	4.45E 04	4.34E 05	1.74E 06	4.45E 03	4.77E 06	1.91E 07	4.90E 04	2.39E 07

ASL MUNITION DUST CLOUD MODEL

PROBLEM NUMBER 1

DETAILED SIZE GROUP RESULTS FOR TIME = 60.0 SECONDS
BURST NUMBER = 1

CLOUD GROUP NUMBER	DUST CENTROID X-COORD. Y-COORD. Z-COORD. (METERS)	CARBON CENTROID X-COORD. Y-COORD. Z-COORD. (METERS)	DUST RADII WIND TRACK CROSS TRACK VERTICAL (METERS)	CARBON RADII WIND TRACK CROSS TRACK VERTICAL (METERS)	TOTAL MASS IN GROUP DUST-MODE A DUST-MODE B CARBON (GRAMS)	CLOUD PATH NUMBER	GROUP MASS PENETRATED DUST-MODE A DUST-MODE B CARBON (GM/CM2)	OPTICAL DEPTH ALONG PATH DUE TO GROUP EXTINCTION	SCATTERING DUST-MODE A DUST-MODE B CARBON	ABSORPTION
MAIN	57.8	57.8	94.9	94.9	7.82E 05	MAIN	0.	0.	0.	0.
1	118.5	118.5	94.9	94.9	2.72E 05	1	0.	0.	0.	0.
	142.9	143.9	48.4	48.4	2.23E 04		0.	0.	0.	0.
BASE	46.4	46.4	57.9	57.9	7.82E 04	BASE	7.93E-04	1.13E 00	6.69E-01	4.62E-01
1	95.0	95.0	57.9	57.9	2.72E 04	1	2.76E-04	3.55E-01	2.04E-01	1.51E-01
	8.9	9.6	25.6	25.6	2.23E 03		2.18E-05	1.12E-01	4.14E-02	7.05E-02
BASE	46.3	46.3	55.9	57.2	1.07E 05	BASE	1.24E-03	1.05E 00	5.77E-01	4.72E-01
2	95.0	95.0	55.9	57.2	8.40E 04	1	9.70E-04	4.97E-01	2.47E-01	2.50E-01
	3.5	6.4	24.9	25.4	2.19E 03		2.43E-05	1.25E-01	4.62E-02	7.86E-02
BASE	46.3	46.3	48.9	54.3	8.19E 04	BASE	6.11E-04	4.62E-01	2.60E-01	2.02E-01
3	95.0	95.0	48.9	54.3	1.05E 05	1	7.86E-04	2.60E-01	1.35E-01	1.25E-01
	-5.3	1.0	22.6	24.4	4.02E 01		4.51E-07	2.32E-03	8.58E-04	1.46E-03
MAIN	57.7	57.8	93.4	94.4	5.40E 05	MAIN	2.34E-08	1.70E-05	9.61E-06	7.41E-06
4	118.4	118.4	93.4	94.4	1.10E 06	1	4.75E-08	1.25E-05	6.58E-06	5.93E-06
	107.4	122.2	47 [illegible]	48.1	2.40E 01		0.	0.	0.	0.
BASE	46.3	46.3	[illegible]	48.0	5.40E 04	BASE	1.77E-05	1.29E-02	7.29E-03	5.63E-03
4	94.9	95.0	37.2	48.0	1.10E 05	1	3.60E-05	9.50E-03	5.00E-03	4.50E-03
	-17.1	-6.2	18.5	22.3	2.40E 00		1.60E-08	8.21E-05	3.04E-05	5.17E-05
MAIN	57.7	57.7	91.6	93.6	3.50E 05	MAIN	9.30E-07	6.67E-04	3.77E-04	2.90E-04
5	118.3	118.4	91.6	93.6	1.07E 06	1	2.85E-06	6.59E-04	3.49E-04	3.10E-04
	88.0	11[illegible].0	46.7	47.7	0.		0.	0.	0.	0.
MAIN	57.7	57.7	89.0	92.4	2.29E 05	MAIN	1.53E-05	1.08E-02	6.14E-03	4.71E-03
6	118.3	118.4	89.0	92.4	1.01E 06	1	6.74E-05	1.44E-02	7.63E-03	6.74E-03
	66.4	95.9	45.5	47.1	0.		0.	0.	0.	0.
MAIN	57.6	57.7	86.0	90.8	1.53E 05	MAIN	1.36E-04	9.59E-02	5.43E-02	4.16E-02
7	118.2	118.3	86.0	90.8	9.41E 05	1	8.32E-04	1.68E-01	8.93E-02	7.87E-02
	43.6	80.6	44.0	46.3	0.		0.	0.	0.	0.

DETAILED SIZE GROUP RESULTS (CONTINUED)

CLOUD GROUP NUMBER	DUST CENTROID X-COORD. Y-COORD. Z-COORD. (METERS)	CARBON CENTROID X-COORD. Y-COORD. Z-COORD. (METERS)	DUST RADII WIND TRACK CROSS TRACK VERTICAL (METERS)	CARBON RADII WIND TRACK CROSS TRACK VERTICAL (METERS)	TOTAL MASS IN GROUP DUST-MODE A DUST-MODE B CARBON (GRAMS)	CLOUD PATH NUMBER	GROUP MASS PENETRATED DUST-MODE A DUST-MODE B CARBON (GM/CM2)	OPTICAL DEPTH ALONG PATH DUE TO GROUP EXTINCTION	SCATTERING DUST-MODE A DUST-MODE B CARBON	ABSORPTION
MAIN	57.6	57.7	82.8	88.8	1.05E 05	MAIN	4.80E-04	3.3JE-01	1.92E-01	1.47E-01
8	118.1	118.3	82.8	88.8	8.65E 05	1	3.96E-03	7.70E-01	4.09E-01	3.60E-01
	20.4	64.4	42.4	45.3	0.		0.	0.	0.	0.
MAIN	57.6	57.7	79.6	86.6	7.33E 04	MAIN	5.07E-04	3.57E-01	2.02E-01	1.55E-01
9	118.0	118.2	79.6	86.6	7.92E 05	1	5.48E-03	1.04E 00	5.51E-01	4.85E-01
	-2.6	47.9	40.9	44.3	0.		0.	0.	0.	0.
MAIN	57.5	57.6	76.6	84.3	5.22E 04	MAIN	1.27E-04	8.90E-02	5.04E-02	3.86E-02
10	117.9	118.2	76.6	84.3	7.22E 05	1	1.75E-03	3.24E-01	1.73E-01	1.52E-01
	-25.0	31.5	39.4	43.2	0.		0.	0.	0.	0.
MAIN	57.5	57.6	73.3	81.5	4.54E 04	MAIN	3.04E-06	2.13E-03	1.21E-03	9.2[illegible]E-04
11	117.8	118.1	73.3	81.5	8.07E 05	1	5.41E-05	9.83E-03	5.23E-03	4.61E-03
	-51.8	11.3	37.8	41.8	0.		0.	0.	0.	0.
MAIN	57.4	57.5	70.5	78.8	3.12E 04	MAIN	2.18E-09	1.53E-06	8.66E-07	6.62E-07
12	117.7	118.0	70.5	78.8	7.19E 05	1	5.03E-08	9.01E-06	4.79E-06	4.22E-06
	-77.2	-8.3	36.4	40.5	0.		0.	0.	0.	0.

ASL MUNITION DUST CLOUD MODEL

PROBLEM NUMBER 1

SUMMARY OF PROPAGATION RESULTS FOR TIME = 60.0 SECONDS

PATH NUMBER	WAVELENGTH (MICRONS) FREQUENCY (GHZ)	PATH COORDINATES(METERS) TRANSMITTER X-COORD. Y-COORD. Z-COORD.	RECEIVER X-COORD. Y-COORD. Z-COORD.	TOTAL TRANSMISSION EXTINCTION SCATTERING ABSORPTION	TOTAL OPTICAL DEPTH EXTINCTION SCATTERING ABSORPTION	OPTICAL BUTIONS BURST NUMBER	DEPTH CONTRI- FROM EACH BURST EXTINCTION SCATTERING ABSORPTION
1	10.4 2.90E 04	1.2 -1000.0 1.7	1.2 1000.0 1.7	7.23E-04 1.96E-02 3.69E-02	7.23E 00 3.93E 00 3.30E 00	1	7.23E 00 3.93E 00 3.30E 00

ASL MUNITION DUST CLOUD MODEL

PROBLEM NUMBER 1

DETAILED SIZE GROUP RESULTS FOR TIME = 80.0 SECONDS
BURST NUMBER = 1

CLOUD GROUP NUMBER	DUST CENTROID X-COORD. Y-COORD. Z-COORD. (METERS)	CARBON CENTROID X-COORD. Y-COORD. Z-COORD. (METERS)	DUST RADII WIND TRACK CROSS TRACK VERTICAL (METERS)	CARBON RADII WIND TRACK CROSS TRACK VERTICAL (METERS)	TOTAL MASS IN GROUP DUST-MODE A DUST-MODE B CARBON (GRAMS)	CLOUD PATH NUMBER	GROUP MASS PENETRATED DUST-MODE A DUST-MODE B CARBON (GM/CM2)	OPTICAL DEPTH ALONG PATH DUE TO GROUP EXTINCTION	SCATTERING DUST-MODE A DUST-MODE B CARBON	ABSORPTION
MAIN	79.2	79.2	109.5	109.5	7.82E 05	MAIN	0.	0.	0.	0.
1	162.4	162.4	109.5	109.5	2.72E 05	1	0.	0.	0.	0.
	167.3	168.6	55.5	55.5	2.23E 04		0.	0.	0.	0.
BASE	68.1	68.1	66.5	66.6	7.82E 04	BASE	2.50E-04	3.57E-01	2.11E-01	1.46E-01
1	139.5	139.5	66.5	66.6	2.72E 04	1	8.71E-05	1.12E-01	6.42E-02	4.76E-02
	8.3	9.2	29.9	29.9	2.23E 03		6.90E-06	3.55E-02	1.31E-02	2.23E-02
BASE	68.0	68.0	64.2	65.7	1.07E 05	BASE	3.45E-04	2.92E-01	1.60E-01	1.31E-01
2	139.5	139.5	64.2	65.7	8.40E 04	1	2.70E-04	1.38E-01	6.88E-02	6.96E-02
	1.1	4.9	29.1	29.6	2.19E 03		7.36E-06	3.78E-02	1.40E-02	2.38E-02
BASE	68.0	68.0	56.2	62.4	8.19E 04	BASE	9.37E-05	7.08E-02	3.98E-02	3.10E-02
3	139.5	139.5	56.2	62.4	1.05E 05	1	1.21E-04	3.99E-02	2.07E-02	1.92E-02
	-10.6	-2.2	26.4	28.5	4.02E 01		1.12E-07	5.77E-[illegible]	2.14E-04	3.64E-04
MAIN	79.2	79.2	107.7	108.8	5.40E 05	MAIN	1.07E-08	[illegible]-06	4.42E-06	3.41E-06
4	162.3	162.4	107.7	108.8	1.10E 06	1	2.18E-08	5.76E-06	3.03E-06	2.73E-06
	121.5	140.7	54.6	55.2	2.40E 01		0.	0.	0.	0.
BASE	68.0	68.0	42.7	55.2	5.40E 04	BASE	3.05E-07	2.22E-04	1.25E-04	9.66E-05
4	139.4	139.5	42.7	55.2	1.10E 05	1	6.19E-07	1.63E-04	8.59E-05	7.73E-05
	-26.4	-11.9	21.6	26.1	2.40E 00		2.21E-09	1.14E-05	4.20E-06	7.15E-06
MAIN	79.1	79.2	105.6	107.9	3.50E 05	MAIN	9.28E-07	6.65E-04	3.76E-04	2.89E-04
5	162.3	162.3	105.6	107.9	1.07E 06	1	2.84E-06	6.58E-04	3.48E-04	3.09E-04
	96.5	124.9	53.6	54.7	0.		0.	0.	0.	0.
MAIN	79.1	79.2	102.6	106.5	2.29E 05	MAIN	1.85E-05	1.31E-02	7.43E-03	5.69E-03
6	162.2	162.3	102.6	106.5	1.01E 06	1	8.16E-05	1.74E-02	9.33E-03	8.16E-03
	68.6	106.7	52.1	54.1	0.		0.	0.	0.	0.
MAIN	79.1	79.1	99.1	104.6	1.53E 05	MAIN	1.51E-04	1.07E-01	6.05E-02	4.63E-02
7	162.1	162.2	99.1	104.6	9.41E 05	1	9.27E-04	1.87E-01	9.95E-02	8.77E-02
	39.2	86.9	50.4	53.1	0.		0.	0.	0.	0.

DETAILED SIZE GROUP RESULTS (CONTINUED)

CLOUD GROUP NUMBER	DUST CENTROID X-COORD. Y-COORD. Z-COORD. (METERS)	CARBON CENTROID X-COORD. Y-COORD. Z-COORD. (METERS)	DUST RADII WIND TRACK CROSS TRACK VERTICAL (METERS)	CARBON RADII WIND TRACK CROSS TRACK VERTICAL (METERS)	TOTAL MASS IN GROUP DUST-MODE A DUST-MODE B CARBON (GRAMS)	CLOUD PATH NUMBER	GROUP MASS PENETRATED DUST-MODE A DUST-MODE B CARBON (GM/CM2)	OPTICAL DEPTH ALONG PATH DUE TO GROUP EXTINCTION	SCATTERING DUST-MODE A DUST-MODE B CARBON	ABSORPTION
MAIN 8	79.0 162.1 9.2	79.1 162.2 66.1	95.4 95.4 48.6	102.3 102.3 52.0	1.05E 05 8.65E 05 0.	MAIN 1	3.38E-04 2.79E-03 0.	2.38E-01 5.42E-01 0.	1.35E-01 2.88E-01 0.	1.03E-01 2.54E-01 0.
MAIN 9	79.0 162.0 -20.4	79.1 162.1 44.8	91.7 91.7 46.8	99.8 99.8 50.7	7.33E 04 7.92E 05 0.	MAIN 1	1.42E-04 1.53E-03 0.	9.99E-02 2.90E-01 0.	5.66E-02 1.54E-01 0.	4.33E-02 1.36E-01 0.
MAIN 10	78.9 161.9 -49.3	79.1 162.1 23.6	88.3 88.3 45.1	97.1 97.1 49.4	5.22E 04 7.22E 05 0.	MAIN 1	8.39E-06 1.16E-04 0.	5.89E-03 2.15E-02 0.	3.34E-03 1.14E-02 0.	2.55E-03 1.01E-02 0.
MAIN 11	78.9 161.7 -83.9	79.0 162.0 -2.5	84.5 84.5 43.2	93.9 93.9 47.9	4.54E 04 8.07E 05 0.	MAIN 1	1.37E-08 2.44E-07 0.	9.60E-06 4.43E-05 0.	5.44E-06 2.36E-05 0.	4.16E-06 2.08E-05 0.

ASL MUNITION DUST CLOUD MODEL

PROBLEM NUMBER 1

SUMMARY OF PROPAGATION RESULTS FOR TIME = 80.0 SECONDS

PATH NUMBER	WAVELENGTH (MICRONS) FREQUENCY (GHZ)	PATH COORDINATES(METERS) TRANSMITTER X-COORD. Y-COORD. Z-COORD.	RECEIVER X-COORD. Y-COORD. Z-COORD.	TOTAL TRANSMISSION EXTINCTION SCATTERING ABSORPTION	TOTAL OPTICAL DEPTH EXTINCTION SCATTERING ABSORPTION	OPTICAL DEPTH CONTRIBUTIONS BURST NUMBER	FROM EACH BURST EXTINCTION SCATTERING ABSORPTION
1	10.4	1.2	1.2	7.38E-02	2.61E 00	1	2.61E 00
	2.90E 04	-1000.0	1000.0	2.42E-01	1.42E 00		1.42E 00
		1.7	1.7	3.05E-01	1.19E 00		1.19E 00

ASL MUNITION DUST CLOUD MODEL

PROBLEM NUMBER 1

DETAILED SIZE GROUP RESULTS FOR TIME = 100.0 SECONDS
BURST NUMBER = 1

CLOUD GROUP NUMBER	DUST CENTROID X-COORD. Y-COORD. Z-COORD. (METERS)	CARBON CENTROID X-COORD. Y-COORD. Z-COORD. (METERS)	DUST RADII WIND TRACK CROSS TRACK VERTICAL (METERS)	CARBON RADII WIND TRACK CROSS TRACK VERTICAL (METERS)	TOTAL MASS IN GROUP DUST-MODE A DUST-MODE B CARBON (GRAMS)	CLOUD PATH NUMBER	GROUP MASS PENETRATED DUST-MODE A DUST-MODE B CARBON (GM/CM2)	OPTICAL DEPTH ALONG PATH DUE TO GROUP EXTINCTION	SCATTERING DUST-MODE A DUST-MODE B CARBON	ABSORPTION
MAIN	100.6	100.6	122.3	122.3	7.82E 05	MAIN	0.	0.	0.	0.
1	206.3	206.3	122.3	122.3	2.72E 05	1	0.	0.	0.	0.
	188.9	190.4	61.8	61.8	2.23E 04		0.	0.	0.	0.
BASE	89.8	89.8	75.1	75.2	7.82E 04	BASE	8.43E-05	1.20E-01	7.11E-02	4.92E-02
1	184.0	184.0	75.1	75.2	2.72E 04	1	2.94E-05	3.77E-02	2.17E-02	1.61E-02
	7.7	8.9	34.0	34.1	2.23E 03		2.34E-06	1.20E-02	4.46E-03	7.58E-03
BASE	89.7	89.7	72.6	74.3	1.07E 05	BASE	1.03E-04	8.72E-02	4.80E-02	3.92E-02
2	184.0	184.0	72.6	74.3	8.40E 04	1	8.07E-05	4.13E-02	2.06E-02	2.08E-02
	-1.3	3.5	33.2	33.7	2.19E 03		2.39E-06	1.23E-02	4.54E-03	7.72E-03
BASE	89.7	89.7	63.5	70.5	8.19E 04	BASE	1.60E-05	1.21E-02	6.78E-03	5.29E-03
3	184.0	184.0	63.5	70.5	1.05E 05	1	2.05E-05	6.80E-03	3.53E-03	3.28E-03
	-15.9	-5.4	30.1	32.5	4.02E 01		3.02E-08	1.55E-04	5.75E-05	9.78E-05
MAIN	100.6	100.6	120.3	121.5	5.40E 05	MAIN	8.62E-09	6.28E-06	3.55E-06	2.73E-06
4	206.2	206.3	120.3	121.5	1.10E 06	1	1.75E-08	4.62E-06	2.43E-06	2.19E-06
	133.0	156.3	60.8	61.5	2.40E 01		0.	0.	0.	0.
BASE	89.7	89.7	48.2	62.3	5.40E 04	BASE	0.	0.	0.	0.
4	183.9	184.0	48.2	62.3	1.10E 05	1	0.	0.	0.	0.
	-35.6	-17.5	24.6	29.7	2.40E 00		3.42E-10	1.76E-06	6.50E-07	1.11E-06
MAIN	100.6	100.6	117.9	120.5	3.50E 05	MAIN	9.76E-07	7.00E-04	3.96E-04	3.04E-04
5	206.2	206.3	117.9	120.5	1.07E 06	1	2.99E-06	6.92E-04	3.66E-04	3.26E-04
	102.4	137.1	59.7	61.0	0.		0.	0.	0.	0.
MAIN	100.5	100.6	114.6	119.0	2.29E 05	MAIN	2.12E-05	1.50E-02	8.52E-03	6.53E-03
6	206.1	206.2	114.6	119.0	1.01E 06	1	9.36E-05	1.99E-02	1.06E-02	9.35E-03
	68.4	114.9	58.0	60.2	0.		0.	0.	0.	0.
MAIN	100.5	100.6	110.7	116.8	1.53E 05	MAIN	1.41E-04	1.00E-01	5.66E-02	4.34E-02
7	206.1	206.2	110.7	116.8	9.41E 05	1	8.67E-04	1.75E-01	9.31E-02	8.20E-02
	32.4	90.7	56.1	59.2	0.		0.	0.	0.	0.

DETAILED SIZE GROUP RESULTS (CONTINUED)

CLOUD GROUP NUMBER	DUST CENTROID X-COORD. Y-COORD. Z-COORD. (METERS)	CARBON CENTROID X-COORD. Y-COORD. Z-COORD. (METERS)	DUST RADII WIND TRACK CROSS TRACK VERTICAL (METERS)	CARBON RADII WIND TRACK CROSS TRACK VERTICAL (METERS)	TOTAL MASS IN GROUP DUST-MODE A DUST-MODE B CARBON (GRAMS)	CLOUD PATH NUMBER	GROUP MASS PENETRATED DUST-MODE A DUST-MODE B CARBON (GM/CM2)	OPTICAL DEPTH ALONG PATH DUE TO GROUP EXTINCTION	SCATTERING DUST-MODE A DUST-MODE B CARBON	ABSORPTION
MAIN 8	100.5 206.0 -4.1	100.5 206.1 65.3	106.5 106.5 54.0	114.3 114.3 57.9	1.05E 05 8.65E 05 0.	MAIN 1	1.75E-04 1.44E-03 0.	1.23E-01 2.81E-01 0.	6.99E-02 1.49E-01 0.	5.35E-02 1.32E-01 0.
MAIN 9	100.4 205.9 -40.3	100.5 206.1 39.3	102.4 102.4 52.0	111.4 111.4 56.5	7.33E 04 7.92E 05 0.	MAIN 1	2.55E-05 2.76E-04 0.	1.80E-02 5.22E-02 0.	1.02E-02 2.77E-02 0.	7.79E-03 2.44E-02 0.
MAIN 10	100.4 205.8 -75.6	100.5 206.0 13.4	98.6 98.6 50.1	108.5 108.5 55.0	5.22E 04 7.22E 05 0.	MAIN 1	3.09E-07 4.27E-06 0.	2.17E-04 7.91E-04 0.	1.23E-04 4.21E-04 0.	9.40E-05 3.70E-04 0.

ASL MUNITION DUST CLOUD MODEL

PROBLEM NUMBER 1

SUMMARY OF PROPAGATION RESULTS FOR TIME = 100.0 SECONDS

PATH NUMBER	WAVELENGTH (MICRONS) FREQUENCY (GHZ)	PATH COORDINATES(METERS) TRANSMITTER X-COORD. Y-COORD. Z-COORD.	RECEIVER X-COORD. Y-COORD. Z-COORD.	TOTAL TRANSMISSION EXTINCTION SCATTERING ABSORPTION	TOTAL OPTICAL DEPTH EXTINCTION SCATTERING ABSORPTION	OPTICAL DEPTH CONTRIBUTIONS BURST NUMBER	FROM EACH BURST EXTINCTION SCATTERING ABSORPTION
1	10.4	1.2	1.2	3.27E-01	1.12E 00	1	1.12E 00
	2.90E 04	-1000.0	1000.0	5.45E-01	6.08E-01		6.08E-01
		1.7	1.7	6.01E-01	5.09E-01		5.09E-01

ASL MUNITION DUST CLOUD MODEL

PROBLEM NUMBER 1

DETAILED SIZE GROUP RESULTS FOR TIME = 120.0 SECONDS
BURST NUMBER = 1

CLOUD GROUP NUMBER	DUST CENTROID X-COORD., Y-COORD., Z-COORD. (METERS)	CARBON CENTROID X-COORD., Y-COORD., Z-COORD. (METERS)	DUST RADII WIND TRACK CROSS TRACK VERTICAL (METERS)	CARBON RADII WIND TRACK CROSS TRACK VERTICAL (METERS)	TOTAL MASS IN GROUP DUST-MODE A DUST-MODE B CARBON (GRAMS)	CLOUD PATH NUMBER	GROUP MASS PENETRATED DUST-MODE A DUST-MODE B CARBON (GM/CM2)	OPTICAL DEPTH ALONG PATH DUE TO GROUP: EXTINCTION	SCATTERING DUST-MODE A DUST-MODE B CARBON	ABSORPTION
MAIN	122.1	122.1	133.8	133.8	7.82E 05	MAIN	0.	0.	0.	0.
1	250.3	250.3	133.8	133.8	2.72E 05	1	0.	0.	0.	0.
	208.4	210.2	67.6	..6	2.23E 04		0.	0.	0.	0.
BASE	111.5	111.5	83.7	83.8	7.82E 04	BASE	3.14E-05	4.47E-02	2.65E-02	1.83E-02
1	228.5	228.5	83.7	83.8	2.72E 04	1	1.09E-05	1.40E-02	8.05E-03	5.97E-03
	7.1	8.5	38.0	38.0	2.23E 03		8.76E-07	4.50E-03	1.67E-03	2.84E-03
BASE	111.4	111.4	80.9	82.8	1.07E 05	BASE	3.42E-05	2.90E-02	1.59E-02	1.30E-02
2	228.5	228.5	80.9	82.8	8.40E 04	1	2.68E-05	1.38E-02	6.84E-03	6.91E-03
	-3.7	2.0	37.0	37.7	2.19E 03		8.55E-07	4.40E-03	1.63E-03	2.77E-03
BASE	111.4	111.4	70.8	78.6	8.19E 04	BASE	3.17E-06	2.40E-03	1.35E-03	1.05E-03
3	228.5	228.5	70.8	78.6	1.05E 05	1	4.08E-06	1.35E-03	7.01E-04	6.51E-04
	-21.3	-0.6	33.6	36.3	4.02E 01		9.12E-09	4.69E-05	1.74E-05	2.95E-05
MAIN	122.0	122.0	131.7	133.0	5.40E 05	MAIN	1.10E-08	8.03E-06	4.54E-06	3.50E-06
4	250.2	250.2	131.7	133.0	1.10E 06	1	2.24E-08	5.91E-06	3.11E-06	2.80E-06
	142.5	170.0	66.5	67.1	2.40E 01		0.	0.	0.	0.
BASE	111.4	111.4	53.8	69.5	5.40E 04	BASE	0.	0.	0.	0.
4	228.4	228.5	53.8	69.5	1.10E 05	1	0.	0.	0.	0.
	-44.9	-23.2	27.5	33.1	2.40E 00		6.21E-11	3.19E-07	1.18E-07	2.01E-07
MAIN	122.0	122.0	129.1	131.9	3.50E 05	MAIN	1.03E-06	7.39E-04	4.18E-04	3.21E-04
5	250.1	250.2	129.1	131.9	1.07E 06	1	3.16E-06	7.30E-04	3.87E-04	3.44E-04
	106.5	147.3	65.2	66.6	0.		0.	0.	0.	0.
MAIN	122.0	122.0	125.5	130.2	2.29E 05	MAIN	2.25E-05	1.60E-02	9.07E-03	6.96E-03
6	250.1	250.1	125.5	130.2	1.01E 06	1	9.97E-05	2.12E-02	1.13E-02	9.96E-03
	66.3	121.2	63.4	65.8	0.		0.	0.	0.	0.
MAIN	121.9	122.0	121.1	127.9	1.53E 05	MAIN	1.13E-04	7.98E-02	4.52E-02	3.46E-02
7	250.0	250.1	121.1	127.9	9.41E 05	1	6.92E-04	1.40E-01	7.42E-02	6.54E-02
	23.9	92.6	61.3	64.6	0.		0.	0.	0.	0.

DETAILED SIZE GROUP RESULTS (CONTINUED)

CLOUD GROUP NUMBER	DUST CENTROID X-COORD. Y-COORD. Z-COORD. (METERS)	CARBON CENTROID X-COORD. Y-COORD. Z-COORD. (METERS)	DUST RADII WIND TRACK CROSS TRACK VERTICAL (METERS)	CARBON RADII WIND TRACK CROSS TRACK VERTICAL (METERS)	TOTAL MASS IN GROUP DUST-MODE A DUST-MODE B CARBON (GRAMS)	CLOUD PATH NUMBER	GROUP MASS PENETRATED DUST-MODE A DUST-MODE B CARBON (GM/CM2)	OPTICAL DEPTH ALONG PATH DUE TO GROUP EXTINCTION	SCATTERING DUST-MODE A DUST-MODE B CARBON	ABSORPTION
MAIN 8	121.9 249.9 -19.1	122.0 250.1 62.7	116.5 116.5 59.0	125.1 125.1 63.2	1.05E 05 8.[illegible]5E 05 0.	MAIN 1	7.06E-05 5.82E-04 0.	4.97E-02 1.13E-01 0.	2.82E-02 6.02E-02 0.	2.16E-02 5.30E-02 0.
MAIN 9	121.8 249.8 -61.8	121.9 250.0 32.1	112.1 112.1 56.8	122.0 122.0 61.7	7.33E 04 7.92E 05 0.	MAIN 1	3.24E-06 3.50E-05 0.	2.28E-03 6.61E-03 0.	1.29E-03 3.52E-03 0.	9.87E-04 3.10E-03 0.
MAIN 10	121.8 249.7 -103.3	121.9 249.9 1.5	107.9 107.9 54.7	119.7 118.7 60.1	5.22E 04 7.22E 05 0.	MAIN 1	6.41E-09 8.86E-08 0.	4.50E-06 1.64E-05 0.	2.55E-06 8.72E-06 0.	1.95E-06 7.68E-06 0.

ASL MUNITION DUST CLOUD MODEL

PROBLEM NUMBER 1

SUMMARY OF PROPAGATION RESULTS FOR TIME = 120.0 SECONDS

PATH NUMBER	WAVELENGTH (MICRONS) FREQUENCY (GHZ)	PATH COORDINATES(METERS) TRANSMITTER X-COORD. Y-COORD. Z-COORD.	RECEIVER X-COORD. Y-COORD. Z-COORD.	TOTAL TRANSMISSION EXTINCTION SCATTERING ABSORPTION	TOTAL OPTICAL DEPTH EXTINCTION SCATTERING ABSORPTION	OPTICAL DEPTH CONTRIBUTIONS FROM EACH BURST BURST NUMBER	EXTINCTION SCATTERING ABSORPTION
1	10.4	1.2	1.2	5.80E-01	5.44E-01	1	5.44E-01
	2.90E 04	-1000.0	1000.0	7.44E-01	2.96E-01		2.96E-01
		1.7	1.7	7.81E-01	2.48E-01		2.48E-01

ASL MUNITION DUST CLOUD MODEL

PROBLEM NUMBER 1

DETAILED SIZE GROUP RESULTS FOR TIME = 140.0 SECONDS
BURST NUMBER = 1

CLOUD GROUP NUMBER	DUST CENTROID X-COORD. Y-COORD. Z-COORD. (METERS)	CARBON CENTROID X-COORD. Y-COORD. Z-COORD. (METERS)	DUST RADII WIND TRACK CROSS TRACK VERTICAL (METERS)	CARBON RADII WIND TRACK CROSS TRACK VERTICAL (METERS)	TOTAL MASS IN GROUP DUST-MODE A DUST-MODE B CARBON (GRAMS)	CLOUD PATH NUMBER	GROUP MASS PENETRATED DUST-MODE A DUST-MODE B CARBON (GM/CM2)	OPTICAL DEPTH ALONG PATH DUE TO GROUP EXTINCTION	SCATTERING DUST-MODE A DUST-MODE B CARBON	ABSORPTION
MAIN	143.5	143.5	144.5	144.5	7.82E 05	MAIN	0.	0.	0.	0.
1	294.2	294.2	144.5	144.5	2.72E 05	1	0.	0.	0.	0.
	226.3	228.4	72.8	72.8	2.23E 04		0.	0.	0.	0.
BASE	133.2	133.2	92.3	92.5	7.82E 04	BASE	1.29E-05	1.84E-02	1.09E-02	7.51E-03
1	273.0	273.0	92.3	92.5	2.72E 04	1	4.49E-06	5.76E-03	3.31E-03	2.45E-03
	6.5	8.2	41.8	41.9	2.23E 03		3.62E-07	1.86E-03	6.89E-04	1.17E-03
BASE	133.1	133.1	89.2	91.3	1.07E 05	BASE	1.27E-05	1.08E-02	5.92E-03	4.84E-03
2	273.0	273.0	89.2	91.3	8.40E 04	1	9.95E-06	5.10E-03	2.54E-03	2.56E-03
	-6.1	0.6	40.8	41.5	2.19E 03		3.40E-07	1.75E-03	6.47E-04	1.10E-03
BASE	133.1	133.1	78.1	86.7	8.19E 04	BASE	7.36E-07	5.56E-04	3.12E-04	2.44E-04
3	273.0	273.0	78.1	86.7	1.05E 05	1	9.46E-07	5.13E-04	1.62E-04	1.51E-04
	-26.6	-11.8	37.0	39.9	4.02E 01		3.10E-09	1.59E-05	5.90E-06	1.00E-05
MAIN	143.4	143.5	142.1	143.6	5.40E 05	MAIN	9.81E-09	7.15E-06	4.04E-06	3.11E-06
4	294.1	294.1	142.1	143.6	1.10E 06	1	1.99E-08	5.26E-06	2.77E-06	2.49E-06
	150.5	182.2	71.7	72.4	2.40E 01		0.	0.	0.	0.
BASE	133.1	133.1	59.3	76.6	5.40E 04	BASE	0.	0.	0.	0.
4	272.9	272.9	59.3	76.6	1.10E 05	1	0.	0.	0.	0.
	-54.1	-28.8	30.3	36.5	2.40E 00		1.33E-11	6.01E-08	2.52E-08	4.29E-08
MAIN	143.4	143.4	139.4	142.4	3.50E 05	MAIN	1.07E-06	7.69E-04	4.35E-04	3.34E-04
5	294.1	294.1	139.4	142.4	1.07E 06	1	3.29E-06	7.60E-04	4.02E-04	3.58E-04
	109.1	156.0	70.3	71.8	0.		0.	0.	0.	0.
MAIN	143.4	143.4	135.4	140.6	2.29E 05	MAIN	2.23E-05	1.58E-02	8.97E-03	6.88E-03
6	[illegible]	294.1	135.4	140.6	1.01E 06	1	9.85E-05	2.10E-02	1.11E-02	9.85E-03
	62.9	126.0	68.3	70.9	0.		0.	0.	0.	0.
MAIN	143.4	143.4	130.8	138.1	1.53E 05	MAIN	7.83E-05	5.54E-02	3.14E-02	2.40E-02
7	293.9	294.0	130.8	138.1	9.41E 05	1	9.60E-04	9.69E-02	5.15E-02	4.54E-02
	14.2	93.2	66.0	69.7	0.		0.	0.	0.	0.

DETAILED SIZE GROUP RESULTS (CONTINUED)

CLOUD GROUP NUMBER	DUST CENTROID X-COORD. Y-COORD. Z-COORD. (METERS)	CARBON CENTROID X-COORD. Y-COORD. Z-COORD. (METERS)	DUST RADII WIND TRACK' CROSS TRACK VERTICAL (METERS)	CARBON RADII WIND TRACK CROSS TRACK VERTICAL (METERS)	TOTAL MASS IN GROUP DUST-MODE A DUST-MODE B CARBON (GRAMS)	CLOUD PATH NUMBER	GROUP MASS PENETRATED DUST-MODE A DUSY-MODE B CARBON (GM/CM2)	OPTICAL DEPTH ALONG PATH DUE TO GROUP EXTINCTION	SCATTERING DUST-MODE A DUST-MODE B CARBON	ABSORPTION
MAIN	143.3	143.4	125.8	135.0	1.05E 05	MAIN	2.31E-05	1.63E-02	9.21E 03	7.05E-03
8	293.8	294.0	125.8	135.0	8.65E 05	1	1.90E-04	3.70E-02	1.97E 02	1.73E-02
	-35.3	58.7	63.6	68.2	.		0.	0.	0.	0.
MAIN	143.3	143.4	121.0	131.7	7.33E 04	MAIN	3.10E-07	2.18E-04	1.23E-04	9.44E-05
9	293.8	293.9	121.0	131.7	7.92E 05	1	3.34E-06	6.32E-04	3.36E-04	2.96E-04
	-84.4	23.5	61.2	66.5	0.		0.	0.	0.	0.

ASL MUNITION DUST CLOUD MODEL

PROBLEM NUMBER 1

SUMMARY OF PROPAGATION RESULTS FOR TIME = 140.0 SECONDS

PATH NUMBER	WAVELENGTH (MICRONS) FREQUENCY (GHZ)	PATH COORDINATES(METERS) TRANSMITTER X-COORD. Y-COORD. Z-COORD.	RECEIVER X-COORD. Y-COORD. Z-COORD.	TOTAL TRANSMISSION EXTINCTION SCATTERING ABSORPTION	TOTAL OPTICAL DEPTH EXTINCTION SCATTERING ABSORPTION	OPTICAL DEPTH CONTRIBUTIONS BURST NUMBER	FROM EACH BURST EXTINCTION SCATTERING ABSORPTION
1	10.4	1.2	1.2	..49E-01	2.89E-01	1	2.89E-01
	2.90E 04	-1000.0	1000.0	8.54E-01	1.50E-01		1.58E-01
		1.7	1.7	8.77E-01	1.32E-01		1.32E-01

SECTION 5
CODE LISTING

In this section we present the FORTRAN card source listings of the ASL-DUST code. In general, each routine defines the principal FORTRAN mnemonics of the variables used within the routine. Routine INPUT defines all input mnemonics. Comment cards are interspersed throughout the routines as a programming aid.

```
C      EXECUTIVE ROUTINE FOR THE ASL MUNITION DUST CLOUD MODEL
C
C      THIS IS THE EXECUTIVE ROUTINE FOR THE COMPUTER CODE PROGRAM FOR
C      THE ASL MUNITION DUST CLOUD MODEL DOCUMENTED IN
C
C                MODELS FOR MUNITION DUST CLOUDS
C                BY JAMES H THOMPSON
C                ASL-CR-79-0005-2, (GE78TMP-99 ), GENERAL ELECTRIC -
C                TEMPO, NOVEMBER 22, 1978
C
C                ASL-DUST. A TACTICAL BATTLEFIELD DUST CLOUD AND
C                PROPAGATION CODE
C                VOLUME 1. MODEL FORMULATIONS
C                VOLUME 2. USERS MANUAL
C                BY JAMES H. THOMPSON
C                GE80TMP-5, GENERAL ELECTRIC - TEMPO, JANUARY 1980
C
C
C
C      SEE SUBROUTINE INPUT FOR THE DEFINITIONS OF VARIABLES IN THE
C      CINPT1 - CINTP7 LABELLED COMMON AREAS. SEE SUBROUTINE DEPTH FOR
C      VARIABLES IN CDEPTH LABELED COMMON
C
       COMMON / CINPT1 / W(10), FH(10), CT(10), CP(10), CV(10), XB(10),
      1                  YB(10), ZB(10), DOB(10), FCM(10), ACV(10),
      2                  PHIBDG(10)
       COMMON / CINPT2 / FREQ(10), XLAMDA(10), XT(10), YT(10), ZT(10),
      1                  XR(10), YR(10), ZR(10)
       COMMON / CINPT3 / XNAR(10), XNAI(10), XNBR(10), XNBI(10), XNCR(10)
      1                , XNCI(10), AMA, SA, AMINA, AMAXA, PA, AMB, SB,
      2                  AMINB, AMAXB, PB, AMC, SC, AMINC, AMAXC, PC
       COMMON / CINPT4 / RHOG, RHOD, RHOC, FH2O, XLC, RMAB, RBASE
       COMMON / CINPT5 / PSF, ALPHA, CDRAG, RHOA, ELEVG, TAIR, TLAPSE,
      1                  ALTIV, VWIND, ALTW, PVW, PHIWDG
       COMMON / CINPT6 / NB, NDG, NRT, NTIME, NPROB, IPRINT
       COMMON / CINPT7 / DGROUP(50), TIME(25)
       COMMON / CDEPTH / TAUEW(10,10), TAUSW(10,10), TAUAW(10,10),
      1                  TAUE(10), TAUS(10), TAUA(10)
C      SET DEFAULT TIMES
       DIMENSION TFLT(25)
       DATA TFLT / 2., 4., 6., 8., 10., 12., 14., 16., 18., 20., 22.5,
      1            25., 27.5, 30., 32.5, 35., 37.5, 40., 45., 50., 55.,
      2            60., 70., 80., 100. /
C
C      SET DEFAULT DIAMETERS OF SIZE GROUPS
       DIMENSION DGFLT(50)
       DATA DGFLT / 5., 10., 20., 30., 40., 50., 60., 70., 80., 90.,
      1             100., 105., 110., 115., 120., 125., 130., 135., 140.,
      2             145., 150., 155., 160., 165., 170., 175., 180., 185.,
      3             190., 195., 200., 210., 220., 230., 240., 250., 260.,
      4             270., 280., 290., 300., 350., 400., 450., 500., 600.,
      5             750., 1000., 5000., 10000. /
C
C      INPUT - OUTPUT TAPE DESIGNATION
       COMMON / TAPE / ITAPE, JTAPE
C      THE INPUT AND OUTPUT TAPE NUMBERS ARE SPECIFIED BY ASSIGNING
C      VALUES TO THE VARIABLES ITAPE AND JTAPE, RESPECTIVELY. THESE ARE
C      PRESENTLY SET TO 5 AND 6, BUT CAN EASILY BE CHANGED BY RESPECIFYING
```

```
C     THE FOLLOWING TWO STATEMENTS
      ITAPE = 5
      JTAPE = 6
C
C     INITIALIZATION SECTION. SET THE DEFAULT VALUES
      RHOG = 1.5
      RHOP = 2.5
      FH2O = 0.15
      AMA = 1.
      SA = 2.2
      AMINA = 0.
      AMAXA = 0.
      PA = 0.
      AMB = 20.
      SB = 2.
      AMINB = 180.
      AMAXB = 1.E4
      PB = 4.
      AMC = 0.5
      SC = 2.
      AMINC = 0.
      AMAXC = 0.
      PC = 0.
      RHOC = 1.5
      XLC = 0.3
      NDG = 50
      DO 1 I = 1, 50
      DGROUP(I) = DGFLT(I)
    1 CONTINUE
      NRT = 1
      FREQ(1) = 1.E5
      XLAMDA(1) = 3.
      XT(1) = 500.
      YT(1) = 50.
      ZT(1) = 2.
      XR(1) = - 500.
      YR(1) = 50.
      ZR(1) = 2.
      XNAR(1) = 1.66
      XNAI(1) = 1.6E-2
      XNBR(1) = 1.66
      XNBI(1) = 1.6E-2
      XNCR(1) = 2.
      XNCI(1) = 1.
      PSF = 4.
      ALPHA = 1.
      CDRAG = 0.8
      RHOA = 1.225E-3
      ELEVG = 0.
      TAIR = 288.
      TLAPSE = - 9.8E-3
      ALTIV = 1.E3
      VWIND = 3.
      PHIWDG = 0.
      RMAH = 0.25
      RBASE = 0.1
      NTIME = 25
      DO 2 I = 1, NTIME
```

```
            TIME(I) = TFLT(I)
          2 CONTINUE
            NPROB = 0
            IPRINT = 0
      C
      C     READ THE INPUT FOR THIS PROBLEM
         10 CALL INPUT
      C
      C     FOR EACH TYPE OF MATERIAL, CALCULATE THE PROPAGATION PARAMETERS
      C     FOR EACH CONTRIBUTING SIZE GROUP FOR EACH FREQUENCY
            CALL PGROUP
      C
      C     CALCULATE THE INITIAL PROPERTIES OF THE DUST CLOUDS FOR EACH BURST
            CALL INITCG
      C
      C     TIME DEPENDENT CALCULATIONS
      C
      C     LOOP OVER THE TIMES
            DO 60 IT = 1, NTIME
            T = TIME(IT)
      C
      C     ZERO OUT THE OPTICAL DEPTH PARAMETERS
            DO 25 IRT = 1, NRT
            TAUE(IRT) = 0.
            TAUS(IRT) = 0.
            TAUA(IRT) = 0.
            DO 25 IW = 1, NW
            TAUEW(IW,IRT) = 0.
            TAUSW(IW,IRT) = 0.
            TAUAW(IW,IRT) = 0.
         25 CONTINUE
      C
      C     LOOP OVER THE BURSTS
            DO 50 IW = 1, NW
            IWC = IW
      C
      C     FOR THIS TIME AND BURST CALCULATE THE LOCATION AND CLOUD SIZE OF
      C     THE ZERO DIAMETER PARTICLES
            CALL TIMECO( T, IWC )
      C
      C     LOOP OVER THE SIZE GROUPS
            DO 40 IDG = 1, NDG
            IDGC = IDG
      C
      C     FOR THIS TIME AND BURST FIND THE LOCATION AND GEOMETRY OF THE
      C     SIZE GROUP
            CALL TIMECG( T, IWC, IDGC )
      C
      C     LOOP OVER THE RECEIVER - TRANSMITTER PAIRS
            DO 30 IRT = 1, NRT
            IRTC = IRT
      C
      C
      C     FOR THIS TIME, BURST, AND SIZE GROUP FIND THE MASS PENETRATED
      C     ALONG THE PATH BETWEEN THIS RECEIVER - TRANSMITTER PAIR DUE TO
      C     EACH MATERIAL IN THE SIZE GROUP
            CALL PATH( IWC, IDGC, IRTC )
      C
```

```
C     FOR THIS TIME, BURST AND SIZE GROUP FIND THE EXTINCTION,
C     SCATTERING AND ABSORPTION OPTICAL DEPTHS ALONG THIS PATH DUE TO
C     EACH MATERIAL IN THE SIZE GROUP. SUM THE CONTRIBUTIONS
      CALL DEPTH( T, INC, IDGC, IRTC )
C
   30 CONTINUE
C
   40 CONTINUE
C
   50 CONTINUE
C
   60 CONTINUE
C
C
C     THIS PROBLEM IS COMPLETED. DO NEXT PROBLEM
      GO TO 10
C
      END
```

```
      SUBROUTINE INPUT
C
C     THIS ROUTINE READS THE INPUT FOR EACH PROBLEM, THEN WRITES THE
C     INPUT VALUES OUT
C
C
C     DEFINITIONS OF VARIABLES IN LABELED COMMON
C
C     W(IW)        = EQUIVALENT TNT YIELD OF BURST IW (LBS TNT)
C     FH(IW)       = FRACTION OF YIELD APPEARING AS HYDRODYNAMIC ENERGY
C                    FOR BURST IW
C     CT(IW)       = INITIAL MAIN CLOUD SHAPE FACTOR FOR THE DIRECTION
C                    ALONG THE SHELL TRACK FOR BURST IW
C     CP(IW)       = INITIAL MAIN CLOUD SHAPE FACTOR FOR THE DIRECTION
C                    PERPENDICULAR TO THE SHELL TRACK FOR BURST IW
C     CV(IW)       = INITIAL MAIN CLOUD SHAPE FACTOR FOR THE VERTICAL
C                    DIRECTION
C     XB(IW)       = X COORDINATE OF THE GROUND SURFACE AT BURST IW
C                    (METERS)
C     YB(IW)       = Y COORDINATE OF THE GROUND SURFACE AT BURST IW
C                    (METERS)
C     ZB(IW)       = Z COORDINATE OF THE GROUND SURFACE AT BURST IW
C                    (METERS)
C     DOB(IW)      = DEPTH OF BURST, IE, DISTANCE BELOW GROUND SURFACE OF
C                    CENTER OF GRAVITY OF BURST IW (METERS)
C     FCM(IW)      = FRACTION OF THE APPARENT CRATER MASS OF BURST IW THAT
C                    IS LOFTED INTO THE AIR
C     ACV(IW)      = APPARENT CRATER VOLUME SCALING FACTOR FOR BURST IW
C                    (CUBIC METERS PER (LB TNT)**1.111 )
C     PHIBDG(IW) = AZIMUTH OF SHELL TRACK OF BURST IW (DEGREES,
C                    MEASURED CLOCKWISE FROM THE Y AXIS)
C     FREQ(IRT)    = FREQUENCY OF TRANSMITTER - RECEIVER PAIR IRT (GHZ)
C     XLAMDA(IRT)= WAVELENGTH OF TRANSMITTER - RECEIVER PAIR IRT
C                    (MICRONS)
C     XT(IRT)      = X COORDINATE OF TRANSMITTER IRT (METERS)
C     YT(IRT)      = Y COORDINATE OF TRANSMITTER IRT (METERS)
C     ZT(IRT)      = Z COORDINATE OF TRANSMITTER IRT (METERS)
C     XR(IRT)      = X COORDINATE OF RECEIVER IRT (METERS)
C     YR(IRT)      = Y COORDINATE OF RECEIVER IRT (METERS)
C     ZR(IRT)      = Z COORDINATE OF RECEIVER IRT (METERS)
C     XNAR(IRT)    = REAL PART OF THE COMPLEX INDEX OF REFRACTION FOR MODE
C                    A DUST PARTICLES AT THE WAVELENGTH OF TRANSMITTER -
C                    RECEIVER IRT
C     XNAI(IRT)    = IMAGINARY PART OF THE COMPLEX INDEX OF REFRACTION FOR
C                    MODE A DUST PARTICLES AT THE WAVELENGTH OF
C                    TRANSMITTER - RECEIVER IRT
C     XNBR(IRT)    = REAL PART OF THE COMPLEX INDEX OF REFRACTION FOR MODE
C                    B DUST PARTICLES AT THE WAVELENGTH OF TRANSMITTER -
C                    RECEIVER IRT
C     XNBI(IRT)    = IMAGINARY PART OF THE COMPLEX INDEX OF REFRACTION FOR
C                    MODE B DUST PARTICLES AT THE WAVELENGTH OF
C                    TRANSMITTER - RECEIVER IRT
C     XNCR(IRT)    = REAL PART OF THE COMPLEX INDEX OF REFRACTION FOR
C                    CARBON PARTICLES AT THE WAVELENGTH OF TRANSMITTER -
C                    RECEIVER IRT
C     XNCI(IRT)    = IMAGINARY PART OF THE COMPLEX INDEX OF REFRACTION FOR
C                    CARBON PARTICLES AT THE WAVELENGTH OF TRANSMITTER -
C                    RECEIVER IRT
```

```
C     AMA       = MEAN DIAMETER OF THE LOG NORMAL DISTRIBUTION FOR MODE
C                 A DUST PARTICLES (MICRONS)
C     SA        = STANDARD DEVIATION PARAMETER OF THE LOG NORMAL
C                 DISTRIBUTION FOR MODE A DUST PARTICLES
C     AMINA     = MINIMUM DIAMETER OF THE POWER LAW DISTRIBUTION FOR
C                 MODE A DUST PARTICLES (MICRONS)
C     AMAXA     = MAXIMUM DIAMETER OF THE POWER LAW DISTRIBUTION FOR
C                 MODE A DUST PARTICLES (MICRONS)
C     AMB       = MEAN DIAMETER OF THE LOG NORMAL DISTRIBUTION FOR MODE
C                 B DUST PARTICLES (MICRONS)
C     SB        = STANDARD DEVIATION PARAMETER OF THE LOG NORMAL
C                 DISTRIBUTION FOR MODE B DUST PARTICLES
C     AMINB     = MINIMUM DIAMETER OF THE POWER LAW DISTRIBUTION FOR
C                 MODE B DUST PARTICLES (MICRONS)
C     AMAXB     = MAXIMUM DIAMETER OF THE POWER LAW DISTRIBUTION FOR
C                 MODE B DUST PARTICLES (MICRONS)
C     AMC       = MEAN DIAMETER OF THE LOG NORMAL DISTRIBUTION FOR
C                 CARBON PARTICLES (MICRONS)
C     SC        = STANDARD DEVIATION PARAMETER OF THE LOG NORMAL
C                 DISTRIBUTION FOR CARBON PARTICLES
C     AMINC     = MINIMUM DIAMETER OF THE POWER LAW DISTRIBUTION FOR
C                 CARBON PARTICLES (MICRONS)
C     AMAXC     = MAXIMUM DIAMETER OF THE POWER LAW DISTRIBUTION FOR
C                 CARBON PARTICLES (MICRONS)
C     RHOG      = BULK DENSITY OF IN SITU SOIL (GM/CM3)
C     RHOD      = BULK DENSITY OF THE LOFTED DUST GRAINS (GM/CM3)
C     RHOC      = BULK DENSITY OF THE CARBON PARTICLES (GM/CM3)
C     FH2O      = SOIL MOISTURE FRACTION (MASS OF WATER IN SOIL DIVIDED
C                 BY TOTAL MASS OF SOIL INCLUDING WATER)
C     XLC       = CARBON YIELD FRACTON (LB OF CARBON PRODUCED PER LB
C                 OF TNT)
C     RMAB      = RATIO OF THE MASS OF MODE A DUST PARTICLES TO THE
C                 MASS OF MODE B DUST PARTICLES IN THE LOFTED CLOUD
C     RBASE     = RATIO OF THE MASS IN THE BASE CLOUD TO THE MASS IN
C                 THE MAIN CLOUD
C     PSF       = ATMOSPHERIC PASQUILL STABILITY FACTOR (1 = A, 2 = B,
C                 3 = C, 4 = D, 5 = E)
C     ALPHA     = AIR ENTRAINMENT FACTOR FOR RISING CLOUD MODEL
C     CDRAG     = DRAG COEFFICIENT FOR RISING CLOUD MODEL
C     RHOA      = AMBIENT AIR DENSITY AT GROUND LEVEL (GM/CM3)
C     ELEVG     = ELEVATION OF GROUND LEVEL (METERS)
C     TAIR      = AIR TEMPERATURE AT GROUND LEVEL (DEGREES K)
C     TLAPSE    = TEMPERATURE LAPSE RATE (DEGREES K/METER)
C     ALTIV     = ALTITUDE ABOVE GROUND OF INVERSION LAYER (METERS)
C     VWIND     = MEAN WIND VELOCITY AT REFERENCE ALTITUDE (METERS/S)
C     ALTW      = WIND REFERENCE ALTITUDE (METERS)
C     PVW       = POWER LAW EXPONENT OF VERTICAL PROFILE OF MEAN WIND
C                 VELOCITY
C     PHIWDG    = AZIMUTH OF MEAN WIND VELOCITY (MEASURED CLOCKWISE
C                 FROM THE Y AXIS) ( DEGREES)
C     NW        = NUMBER OF BURSTS
C     NDG       = NUMBER OF PARTICLE DIAMETER SIZE GROUPS
C     NRT       = NUMBER OF TRANSMITTER - RECEIVER PAIRS
C     NTIME     = NUMBER OF CALCULATION TIMES
C     NPROB     = NUMBER OF THE PRESENT CASE BEING CALCULATED
C     IPRINT    = PRINT CONTROL OPTION (0 = PRINT DETAILS OF PATH
C                 INTEGRATION, 1 = PRINT ONLY SUMMARY OF THE PATH
C                 INTEGRATION)
```

```
C     DGROUP(IDG)= MAXIMUM DIAMETER OF THE PARTICLES IN THE IDG SIZE
C                  GROUP (MICRONS)
C     TIME(IT)   = THE IT CALCULATION TIME (SECONDS)
C
C
      COMMON / CINPT1 / W(10), FH(10), CT(10), CP(10), CV(10), XB(10),
     1                  YB(10), ZB(10), DOB(10), FCM(10), ACV(10),
     2                  PHIBDG(10)
      COMMON / CINPT2 / FREQ(10), XLAMDA(10), XT(10), YT(10), ZT(10),
     1                  XR(10), YR(10), ZR(10)
      COMMON / CINPT3 / XNAR(10), XNAI(10), XNBR(10), XNBI(10), XNCR(10)
     1                , XNCI(10), AMA, SA, AMINA, AMAXA, PA, AMB, SB,
     2                  AMINB, AMAXB, PB, AMC, SC, AMINC, AMAXC, PC
      COMMON / CINPT4 / RHOG, RHOD, RHOC, FH2O, XLC, RMAB, RBASE
      COMMON / CINPT5 / PSF, ALPHA, CDRAG, RHOA, ELEVG, TAIR, TLAPSE,
     1                  ALTIV, VWIND, ALTW, PVW, PHIWDG
      COMMON / CINPT6 / NW, NDG, NRT, NTIME, NPROB, IPRINT
      COMMON / CINPT7 / DGROUP(50), TIME(25)
      COMMON / TAPE / ITAPE, JTAPE
C
      DIMENSION INDEX(50), HPSF(6), X(8), CARD(15)
      DATA INDEX / 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15,
     1             16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28,
     2             29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41,
     3             42, 43, 44, 45, 46, 47, 48, 49, 50 /
      DATA HPSF / 1HA, 1HB, 1HC, 1HD, 1HE, 1HF /
      DATA CARD / 1HA, 1HB, 1HC, 1HD, 1HE, 1HF, 1HG, 1HH, 1HI, 1HJ, 1HK,
     1             1HL, 1HM, 1HN, 1HO /
      DATA BLANK / 1H /
C
      NCARD = 0
      NA = 0
      NB = 0
      NC = 0
      NJ = 0
      NK = 0
C
C     READ NEXT INPUT CARD
    1 READ(ITAPE, 2) XCARD, ( X(J), J = 1, 8 )
    2 FORMAT( A1, E9.0, 7E10.0 )
C
C     CHECK IF FIRST COLUMN IS BLANK, WHICH SIGNIFIES END OF INPUT DATA
C     FOR THIS PROBLEM
      IF( XCARD .NE. BLANK ) GO TO 6
C
C     CHECK IF END OF JOB ( TWO BLANK CARDS IN A ROW )
      IF( NCARD .EQ. 0 ) STOP
C
C     INPUT HAS BEEN READ, SET COUNTERS, FILL IN ANY DEFAULT VALUES
      IF( NA .GT. 0 ) NW = NA
      IF( NC .GT. 0 ) NRT = NC
      IF( NJ .GT. 0 ) NDG = NJ
      IF( NK .GT. 0 ) NTIME = NK
      IF( NK .EQ. 0 ) GO TO 1
      NPROB = NPROB + 1
C
C     CHECK IF THERE ARE MORE GROUP A SETS THAN GROUP B SETS, IF SO FILL
C     IN REST OF GROUP B SETS WITH DEFAULT VALUES
```

```
      NDIF = NW - NB
      IF( NDIF .LE. 0 ) GO TO 4
      NB1 = NB + 1
      NEND = NB + NDIF
      DO 3 N = NB1, NEND
      DUR(N) = 0.
      FCM(N) = 0.25
      ACV(N) = 0.03
      PHIBDG(N) = 0.
    3 CONTINUE
C
C     CHECK IF THERE ARE MORE GROUP C SETS THAN GROUP D SETS, IF SO FILL
C     IN REST OF GROUP D SETS WITH DEFAULT VALUES
    4 NDIF = NRT - ND
      IF( NDIF .LE. 0 ) GO TO 100
      ND1 = ND1 + 1
      NEND = ND + NDIF
      DO 5 N = ND1, NEND
      XNAR(N) = 1.66
      XNAI(N) = 1.6E-2
      XNBR(N) = 1.66
      XNBI(N) = 1.6E-2
      XNCR(N) = 2.
      XNCI(N) = 1.
    5 CONTINUE
C
C     WRITE OUT THE INPUT DATA FOR THIS PROBLEM
      GO TO 100
C
C
C     GO TO THE APPROPRIATE INPUT GROUP. IF NO VALUE IS PROVIDED FOR A
C     PARAMETER, USE DEFAULT VALUE
    6 DO 7 ICARD = 1, 15
      I = ICARD
      IF( XCARD .EQ. CARD(I) ) GO TO 8
    7 CONTINUE
      GO TO 1
    8 NCARD = NCARD + 1
      GO TO( 10, 15, 20, 30, 40, 45, 48, 50, 55, 60, 65, 70, 80 ), I
C
C     INPUT GROUP A, YIELD, HYDRO FRACTION, SHAPE FACTORS, BURST
C     COORDINATES
   10 IF( X(1) .LE. 0. ) GO TO 1
      NA = NA + 1
      W(NA) = X(1)
      FH(NA) = 0.5
      IF( X(2) .GT. 0. ) FH(NA) = X(2)
      CT(NA) = 1.
      IF( X(3) .GT. 0. ) CT(NA) = X(3)
      CP(NA) = 1.
      IF( X(4) .GT. 0. ) CP(NA) = X(4)
      CV(NA) = 1.
      IF( X(5) .GT. 0. ) CV(NA) = X(5)
      XB(NA) = X(6)
      YB(NA) = X(7)
      ZB(NA) = X(8)
      GO TO 1
C
```

```
C      INPUT GROUP B, DEPTH OF BURST, FRACTION OF APPARENT MASS LOFTED,
C      LOADING FACTOR, SHELL TRACK AZIMUTH
    15 NB = NB + 1
       DOB(NB) = X(1)
       FCM(NB) = 0.25
       IF( X(2) .GT. 0. ) FCM(NB) = X(2)
       ACV(NB) = 0.03
       IF( X(3) .GT. 0. ) ACV(NB) = X(3)
       PHIBDG(NB) = X(4)
       GO TO 1
C
C      INPUT GROUP C, FREQUENCY OR WAVELENGTH, COORDINATES OF TRANSMITTER
C      AND RECEIVER
    20 NC = NC + 1
       IF( X(1) .EQ. 0. .AND. X(2) .EQ. 0. ) GO TO 22
       IF( X(2) .EQ. 0. ) GO TO 21
       XLAMDA(NC) = X(2)
       FREQ(NC) = 3.E5 / XLAMDA(NC)
       GO TO 23
    21 FREQ(NC) = X(1)
       XLAMDA(NC) = 3.E5 / FREQ(NC)
       GO TO 23
    22 FREQ(NC) = 1.E5
       XLAMDA(NC) = 3.
    23 IF( X(3) .EQ. 0. .AND. X(4) .EQ. 0. .AND. X(5) .EQ. 0. ) GO TO 24
       XT(NC) = X(3)
       YT(NC) = X(4)
       ZT(NC) = X(5)
       GO TO 25
    24 XT(NC) = 500.
       YT(NC) = 50.
       ZT(NC) = 2.
    25 IF( X(6) .EQ. 0. .AND. X(7) .EQ. 0. .AND. X(8) .EQ. 0. ) GO TO 26
       XR(NC) = X(6)
       YR(NC) = X(7)
       ZR(NC) = X(8)
       GO TO 27
    26 XR(NC) = - 500.
       YR(NC) = 50.
       ZR(NC) = 2.
    27 GO TO 1
C
C      INPUT GROUP D, INDICIES OF REFRACTION FOR MODE A DUST, MODE B DUST
C      AND CARBON FOR EACH FREQUENCY
    30 ND = ND + 1
       XNAR(ND) = 1.66
       IF( X(1) .GT. 0. ) XNAR(ND) = X(1)
       XNAI(ND) = 1.6E-2
       IF( X(2) .GT. 0. ) XNAI(ND) = X(2)
       XNBR(ND) = 1.66
       IF( X(3) .GT. 0. ) XNBR(ND) = X(3)
       XNBI(ND) = 1.6E-2
       IF( X(4) .GT. 0. ) XNBI(ND) = X(4)
       XNCR(ND) = 2.
       IF( X(5) .GT. 0. ) XNCR(ND) = X(5)
       XNCI(ND) = 1.
       IF( X(6) .GT. 0. ) XNCI(ND) = X(6)
       GO TO 1
```

```
C
C     INPUT GROUP E, DENSITIES OF SOIL, DUST GRAINS AND CARBON, SOIL
C     MOISTURE CONTENT, CARBON YIELD FRACTION, RATIOS OF MODE A TO MODE
C     B MASS AND BASE TO MAIN CLOUD MASS
   40 RHOG = 1.5
      IF( X(1) .GT. 0. ) RHOG = X(1)
      RHOD = 2.5
      IF( X(2) .GT. 0. ) RHOD = X(2)
      FH2O = 0.15
      IF( X(3) .GT. 0. ) FH2O = X(3)
      RHOC = 1.5
      IF( X(4) .GT. 0. ) RHOC = X(4)
      XLC = 0.3
      IF( X(5) .GT. 0. ) XLC = X(5)
      RMAB = 0.25
      IF( X(6) .GT. 0. ) RMAB = X(6)
      RBASE = 0.1
      IF( X(7) .GT. 0. ) RBASE = X(7)
      GO TO 1
C
C     INPUT GROUPS F, G, AND H, PROBABILITY DISTRIBUTION PARAMETERS FOR
C     THE MODE A, MODE B, AND CARBON PARTICLES
   45 IF( X(1) * X(2) .LE. 0. .AND. X(3) * X(4) * X(5) .LE. 0. ) GO TO 1
      AMA = X(1)
      SA = X(2)
      AMINA = X(3)
      AMAXA = X(4)
      PA = X(5)
      GO TO 1
   48 IF( X(1) * X(2) .LE. 0. .AND. X(3) * X(4) * X(5) .LE. 0. ) GO TO 1
      AMB = X(1)
      SB = X(2)
      AMINB = X(3)
      AMAXB = X(4)
      PB = X(5)
      GO TO 1
   50 IF( X(1) * X(2) .LE. 0. .AND. X(3) * X(4) * X(5) .LE. 0. ) GO TO 1
      AMC = X(1)
      SC = X(2)
      AMINC = X(3)
      AMAXC = X(4)
      PC = X(5)
      GO TO 1
C
C     INPUT GROUP I, ATMOSPHERIC AND RISING CLOUD PARAMETERS
   55 PSF = 0.
      IF( X(1) .GT. 0. ) PSF = X(1)
      ALPHA = 1.
      IF( X(2) .GT. 0. ) ALPHA = X(2)
      CDRAG = 0.8
      IF( X(3) .GT. 0. ) CDRAG = X(3)
      RHOA = X(4)
      ELEVG = X(5)
      IF( RHOA .LE. 1.E-4 ) RHOA = 1.225E-3 * EXP( - ELEVG / 8.4E3 )
      TAIR = 288.
      IF( X(6) .GT. 0. ) TAIR = X(6)
      TLAPSE = - 9.8E-3
      IF( X(7) .NE. 0. ) TLAPSE = X(7)
```

```
      ALTIV = 1.E3
      IF( X(8) .GT. 0. ) ALTIV = X(8)
      GO TO 1
C
C     INPUT GROUP J, MEAN WIND VELOCITY, WIND REFERENCE ALTITUDE, POWER
C     LAW EXPONENT OF VERTICAL PROFILE, WIND AZIMUTH
   60 VWIND = 3.
      IF( X(1) .GT. 0. ) VWIND = X(1)
      ALTW = 10.
      IF( X(2) .GT. 0. ) ALTW = X(2)
      PVW = 0.1
      IF( X(3) .GT. 0. ) PVW = X(3)
      PHIWDG = X(4)
      GO TO 1
C
C     INPUT GROUP K, MAXIMUM DIAMETERS OF PARTICLES IN THE SIZE GROUPS
   65 DO 67 N = 1, 8
      IF( X(N) .LE. 0. ) GO TO 67
      IF( NJ .EQ. 0 ) GO TO 66
      IF( X(N) .LE. DGROUP(NJ) ) GO TO 67
   66 NJ = NJ + 1
      DGROUP(NJ) = X(N)
   67 CONTINUE
      GO TO 1
C
C     INPUT GROUP L, CALCULATION TIMES
   70 DO 72 N = 1, 8
      IF( X(N) .LE. 0. ) GO TO 72
      IF( NK .EQ. 0 ) GO TO 71
      IF( X(N) .LE. TIME(NK) ) GO TO 72
   71 NK = NK + 1
      TIME(NK) = X(N)
   72 CONTINUE
      GO TO 1
C
C     INPUT GROUP M, CONTROL OPTIONS
   80 IPRINT = 0
      IF( X(1) .GT. 0. ) IPRINT = 1
      GO TO 1
C
C
C     THIS SECTION WRITES OUT THE INPUT DATA FOR THIS PROBLEM
  100 WRITE(JTAPE, 101) NPROB
  101 FORMAT(1H1,69H                                              ASL MUNITION
     . DUST CLOUD MODEL //
     21H0,68H                                         INPUT DATA FOR PROBL
     3EM NUMBER , I3 //
     41H0,70H                                         MUNITION AND CRATER
     5 PARAMETERS /
     61H0,129HBURST   YIELD    HYDRO    INITIAL SHAPE FACTORS     BURST
     7POINT  COORDINATES     DEPTH OF   LOFTED      LOADING    SHELL TRAC
     8K/
     91H ,123H      (LB TNT)  FRACTION  ALONG  CROSS  VERTICAL  X COORD.
     1  Y COORD.  Z COORD.   BURST        MASS         FACTOR        AZIMUTH/
     21H ,122H                          TRACK  TRACK              (METERS)
     3  (METERS)  (METERS)  (METERS)  FRACTION  (M3/LB TNT1.1)   (DEG) )
      WRITE(JTAPE, 102) ( ( I, W(I), FH(I), CT(I), CP(I), CV(I), XB(I),
     1YB(I), ZB(I), DOB(I), FCM(I), ACV(I), PHIBDG(I) ), I = 1, NW )
```

```
102 FORMAT(1H , I3, F9.1, F9.1 , F9.1, F7.1, F8.1, F12.1, F10.1, F10.1
   1, F9.1, F10.2, 1PE15.2, 0PF12.1 )
    WRITE(JTAPE, 103) RHOG, FH2O, RHOD, AMA, SA, AMINA, AMAXA, PA,
   1                  RHOD, AMB, SB, AMINB, AMAXB, PB, RHOC, AMC, SC,
   2                  AMINC, AMAXC, PC, XLC, RMAB, RBASE
103 FORMAT(1H0,22HBULK DENSITY OF SOIL =, F4.1, 7H GM/CM3 /
   11H , 24HSOIL MOISTURE FRACTION =, F5.2 /
   21H0,77H                                        SIZE PROBABILITY DISTR
   3IBUTION PARAMETERS / 1H0,
   479H           DENSITY       MEAN       STANDARD     MINIMUM      MAXIM
   5UM      POWER LAW / 1H ,
   678HMATERIAL    (GM/CM3)   DIAMETER    DEVIATION    DIAMETER     DIAME
   7TER     EXPONENT / 1H ,
   867H                      (MICRONS)    PARAMETER    (MICRONS)    (MICR
   9ONS) /
   11H , 8HDUST - A, F9.2, F12.2, F12.1, F13.1, F13.1, F10.1 /
   21H , 8HDUST - B, F9.2, F12.2, F12.1, F13.1, F13.1, F10.1 /
   31H , 6HCARBON, F11.2, F12.2, F12.1 , F13.1, F13.1, F10.1 /
   41H0,23HCARBON YIELD FRACTION =, F5.2 /
   51H ,29HRATIO MODE A TO MODE B MASS =, F5.2 /
   61H , 31HRATIO BASE TO MAIN CLOUD MASS =, F5.2 // )
    N = MINO( 10, NDG )
    WRITE(JTAPE, 104) ( INDEX(I), I = 1, N )
104 FORMAT(1H0,80H                                  MAXIMUM DIAMETERS OF
   1PARTICLES IN EACH SIZE GROUP /
   21H0, 17HSIZE GROUP NUMBER, I4, 9I11 )
    WRITE(JTAPE, 105) ( DGROUP(I), I = 1, N )
105 FORMAT(1H ,16HMAXIMUM DIAMETER, F7.1, 9F11.1 )
    WRITE(JTAPE, 106)
106 FORMAT(1H ,13H    (MICRONS) )
    DO 109 I = 1, 4
    NS = 10 * I + 1
    NF = NS + 9
    IF( NDG .LT. NS ) GO TO 110
    NF = MINO( NF, NDG )
    WRITE(JTAPE, 107) ( INDEX(N), N = NS, NF )
107 FORMAT(1H0,11X, 10I11 )
    WRITE(JTAPE, 108) ( DGROUP(N), N = NS, NF )
108 FORMAT(1H , 12X, 10F11.1 )
109 CONTINUE
110 WRITE(JTAPE, 111) NPROB
111 FORMAT(1H1,65H                                        INPUT DATA FOR P
   1ROBLEM NUMBER, I3, 12H (CONTINUED) //
   21H0, 74H                                          TRANSMITTER - REC
   3EIVER PARAMETERS /
   41H0, 90H PAIR   FREQUENCY  WAVELENGTH     TRANSMITTER COORDINATES
   5             RECEIVER COORDINATES   /
   61H , 95HNUMBER     (GHZ)     (MICRONS)     X COORD.    Y COORD.   Z CO
   7ORD.    X COORD.    Y COORD.    Z COORD.  /
   81H , 95H                                   (METERS)    (METERS)   (MET
   9ERS)    (METERS)    (METERS)    (METERS)   )
    WRITE(JTAPE, 112) ( ( I, FREQ(I), XLAMDA(I), XT(I), YT(I), ZT(I),
   1 XR(I), YR(I), ZR(I) ), I = 1, NRT )
112 FORMAT(1H , I3, 1PE14.2, 0PF10.1, F12.1, 5F11.1 )
    WRITE(JTAPE, 113) ( ( I, FREQ(I), XLAMDA(I), XNAR(I), XNAI(I),
   1                  XNBR(I), XNBI(I), XNCR(I), XNCI(I) ), I = 1, NRT )
113 FORMAT( 1H0/ 1H0,
   168H                                         INDICIES OF REFRA
```

```
     2CTION / 1H0,
     392H PAIR   FREQUENCY  WAVELENGTH     DUST - MODE A            DUST
     4 - MODE B                  CARBON / 1H ,
     5100HNUMBER    (GHZ)    (MICRONS)   REAL PART   IMAG PART   REAL PA
     6RT   IMAG PART   REAL PART   IMAG PART /
     7 ( 1H , I3, 1PE14.2, 0PF10.1, F10.2, 1PE14.2, 0PF10.2, 1PE14.2,
     8 0PF10.2, 1PE14.2 ) )
      IPSF = IFIX( PSF )
      APSF = HPSF(IPSF)
      WRITE(JTAPE, 114) APSF, ALPHA, CDRAG, RHOA, ELEVG, TAIR, TLAPSE,
     1 ALTIV, VWIND, ALTH, PVW, PHIWDG
  114 FORMAT(1H0/
     11H0,68H                                              ATMOSPHERIC P
     2ARAMETERS /
     31H0, 98HPASQUILL   CLOUD ALPHA  CLOUD DRAG   AIR DENSITY   GROUND
     4   GROUND AIR   TEMPERATURE    INVERSION /
     51H ,101HSTABILITY  ENTRAINMENT  COEFFICIENT   AT GROUND   ELEVATIO
     6N  TEMPERATURE  LAPSE RATE   LAYER ALTITUDE /
     71H , 98HFACTOR          FACTOR                  (GM/CM3)    (METERS)
     8      (DEG K)     (DEG K/ M)        (METERS)  /
     9/1H ,2X, A1, F15.1, F12.1, 1PE17.2, 0PF11.  , F11.1, 1PE14.1,
     1 0PF15.1 /
     21H0,47HMEAN WIND  WIND REFERENCE  WIND VERTICAL   WIND /
     31H ,49HVELOCITY      ALTITUDE     PROFILE POWER  AZIMUTH /
     41H ,48H (M/S)          (METERS)     LAW EXPONENT    (DEG) /
     51H , F6.1, F14.1, F15.2, F13.1 )
C
      RETURN
C
      END
```

```
      SUBROUTINE PGROUP
C
C     THIS SUBROUTINE IS THE EXECUTIVE ROUTINE FOR THE CALCULATION OF
C     THE PROPAGATION PARAMETERS FOR EACH CONTRIBUTING SIZE GROUP FOR
C     EACH TYPE OF PARTICULATE MATERIAL FOR EACH FREQUENCY. THIS ROUTINE
C     SETS UP THE INPUT TO SUBROUTINE CGROUP, STORES THE OUTPUT IN THE
C     APPROPRIATE VARIABLES, AND AFTER ALL CALCULATIONS ARE COMPLETE
C     WRITES OUT THE RESULTS
C
C
C     INPUTS FROM CINPT COMMON AREAS
C     RHOD   = DENSITY OF THE DUST GRAINS (GM/CM3)
C     RHOC   = DENSITY OF THE CARBON PARTICULATES (GM/CM3)
C     XNAR   = REAL PART OF THE INDEX OF REFRACTION FOR MODE A DUST
C              PARTICULATES
C     XNAI   = IMAGINARY PART OF THE INDEX OF REFRACTION FOR MODE A DUST
C              PARTICULATES
C     XNBR   = REAL PART OF THE INDEX OF REFRACTION FOR MODE B DUST
C              PARTICULATES
C     XNBI   = IMAGINARY PART OF THE INDEX OF REFRACTION FOR MODE B DUST
C              PARTICULATES
C     XNCR   = REAL PART OF THE INDEX OF REFRACTION FOR CARBON PARTICLES
C     XNCI   = IMAGINARY PART OF THE INDEX OF REFRACTION FOR CARBON
C              PARTICULATES
C     AMA    = LOG NORMAL MEAN DIAMETER PARAMETER FOR MODE A DUST
C              PARTICLES (MICRONS)
C     AMB    = LOG NORMAL MEAN DIAMETER PARAMETER FOR MODE B DUST
C              PARTICLES (MICRONS)
C     AMC    = LOG NORMAL MEAN DIAMETER PARAMETER FOR CARBON PARTICLES
C              (MICRONS)
C     SA     = LOG NORMAL STANDARD DEVIATION PARAMETER FOR MODE A DUST
C              PARTICLES
C     SB     = LOG NORMAL STANDARD DEVIATION PARAMETER FOR MODE B DUST
C              PARTICLES
C     SC     = LOG NORMAL STANDARD DEVIATION PARAMETER FOR CARBON
C              PARTICLES
C     AMINA  = POWER LAW MINIMUM DIAMETER FOR MODE A DUST PARTICLES.
C              (MICRONS)
C              THIS IS THE DIAMETER AT WHICH THE LOG NORMAL AND POWER
C              LAW PROBABILITY DISTRIBUTIONS ARE JOINED TO FORM THE
C              HYBRID PROBABILITY DISTRIBUTION
C     AMINB  = POWER LAW MINIMUM DIAMETER FOR MODE B DUST PARTICLES.
C              (MICRONS)
C     AMINC  = POWER LAW MINIMUM DIAMETER FOR CARBON PARTICLES
C              (MICRONS)
C     AMAXA  = POWER LAW MAXIMUM DIAMETER FOR MODE A DUST PARTICLES
C              (MICRONS)
C     AMAXB  = POWER LAW MAXIMUM DIAMETER FOR MODE B DUST PARTICLES
C              (MICRONS)
C     AMAXC  = POWER LAW MAXIMUM DIAMETER FOR CARBON PARTICLES
C              (MICRONS)
C     PA     = EXPONENT FOR POWER LAW PROBABILITY DISTRIBUTION FOR THE
C              MODE A DUST PARTICLES
C     PB     = EXPONENT FOR POWER LAW PROBABILITY DISTRIBUTION FOR THE
C              MODE B DUST PARTICLES
C     PC     = EXPONENT FOR POWER LAW PROBABILITY DISTRIBUTION FOR THE
C              CARBON PARTICLES
C     DGROUP = ARRAY OF MAXIMUM DIAMETERS OF PARTICLES IN EACH SIZE
```

```
C                    GROUP (MICRONS)
C       XLAMDA = ARRAY OF THE WAVELENGTHS OF THE TRANSMITTER - RECEIVER
C                    PAIRS (MICRONS)
C
C       OUTPUTS TO CPGRP COMMON
C       FNA(I)     = NUMBER FRACTION OF PARTICLES IN SIZE GROUP I FOR MODE
C                    A DUST PARTICLES (RATIO OF NUMBER OF PARTICLES IN SIZE
C                    GROUP TO TOTAL NUMBER OF PARTICLES IN DISTRIBUTION )
C       FNB(I)     = NUMBER FRACTION OF PARTICLES IN SIZE GROUP I FOR MODE
C                    B DUST PARTICLES
C       FNC(I)     = NUMBER FRACTION OF PARTICLES IN SIZE GROUP I FOR
C                    CARBON PARTICLES
C       FMA(I)     = MASS FRACTION FOR SIZE GROUP I FOR MODE A DUST
C                    PARTICLES ( RATIO OF MASS OF PARTICLES IN SIZE GROUP I
C                    TO TOTAL MASS IN DISTRIBUTION )
C       FMB(I)     = MASS FRACTION FOR SIZE GROUP I FOR MODE B DUST
C                    PARTICLES
C       FMC(I)     = MASS FRACTION FOR SIZE GROUP I FOR CARBON PARTICLES
C       PNGA(I)    = NUMBER OF PARTICLES PER GRAM OF MATERIAL IN SIZE GROUP
C                    I FOR MODE A DUST PARTICLES (NUMBER/GM)
C       PNGB(I)    = NUMBER OF PARTICLES PER GRAM OF MATERIAL IN SIZE GROUP
C                    I FOR MODE B DUST PARTICLES (NUMBER/GM)
C       PNGC(I)    = NUMBER OF PARTICLES PER GRAM OF MATERIAL IN SIZE GROUP
C                    I FOR CARBON PARTICLES (NUMBER/GM)
C       SIGAA(I,J) = AVERAGE ABSORPTION CROSS SECTION PER PARTICLE IN SIZE
C                    GROUP I FOR WAVELENGTH J FOR MODE A DUST PARTICLES
C                    (CM2)
C       SIGAB(I,J) = AVERAGE ABSORPTION CROSS SECTION PER PARTICLE IN SIZE
C                    GROUP I FOR WAVELENGTH J FOR MODE B DUST PARTICLES
C                    (CM2)
C       SIGAC(I,J) = AVERAGE ABSORPTION CROSS SECTION PER PARTICLE IN SIZE
C                    GROUP I FOR WAVELENGTH J FOR CARBON PARTICLES (CM2)
C       SIGSA(I,J) = AVERAGE SCATTERING CROSS SECTION PER PARTICLE IN SIZE
C                    GROUP I FOR WAVELENGTH J FOR MODE A DUST PARTICLES
C                    (CM2)
C       SIGSB(I,J) = AVERAGE SCATTERING CROSS SECTION PER PARTICLE IN SIZE
C                    GROUP I FOR WAVELENGTH J FOR MODE B DUST PARTICLES
C                    (CM2)
C       SIGSC(I,J) = AVERAGE SCATTERING CROSS SECTION PER PARTICLE IN SIZE
C                    GROUP I FOR WAVELENGTH J FOR CARBON PARTICLES (CM2)
C       SIGEA(I,J) = AVERAGE EXTINCTION CROSS SECTION PER PARTICLE IN SIZE
C                    GROUP I FOR WAVELENGTH J FOR MODE A DUST PARTICLES
C                    (CM2)
C       SIGEB(I,J) = AVERAGE EXTINCTION CROSS SECTION PER PARTICLE IN SIZE
C                    GROUP I FOR WAVELENGTH J FOR MODE B DUST PARTICLES
C                    (CM2)
C       SIGEC(I,J) = AVERAGE EXTINCTION CROSS SECTION PER PARTICLE IN SIZE
C                    GROUP I FOR WAVELENGTH J FOR CARBON PARTICLES (CM2)
C       SIGBA(I,J) = AVERAGE BACKSCATTER CROSS SECTION PER PARTICLE IN
C                    SIZE GROUP I FOR WAVELENGTH J FOR MODE A DUST
C                    PARTICLES (CM2)
C       SIGBB(I,J) = AVERAGE BACKSCATTER CROSS SECTION PER PARTICLE IN
C                    SIZE GROUP I FOR WAVELENGTH J FOR MODE B DUST
C                    PARTICLES (CM2)
C       SIGBC(I,J) = AVERAGE BACKSCATTER CROSS SECTION PER PARTICLE IN
C                    SIZE GROUP I FOR WAVELENGTH J FOR CARBON PARTICLES
C                    (CM2)
C       CMUAA(I,J) = MASS ABSORPTION COEFFICIENT FOR SIZE GROUP I AT
```

```
C                    WAVELENGTH J FOR MODE A DUST PARTICLES (CM2/GM)
C      CMUAB(I,J) = MASS ABSORPTION COEFFICIENT FOR SIZE GROUP I AT
C                    WAVELENGTH J FOR MODE B DUST PARTICLES (CM2/GM)
C      CMUAC(I,J) = MASS ABSORPTION COEFFICIENT FOR SIZE GROUP I AT
C                    WAVELENGTH J FOR CARBON PARTICLES (CM2/GM)
C      CMUSA(I,J) = MASS SCATTERING COEFFICIENT FOR SIZE GROUP I AT
C                    WAVELENGTH J FOR MODE A DUST PARTICLES (CM2/GM)
C      CMUSB(I,J) = MASS SCATTERING COEFFICIENT FOR SIZE GROUP I AT
C                    WAVELENGTH J FOR MODE B DUST PARTICLES (CM2/GM)
C      CMUSC(I,J) = MASS SCATTERING COEFFICIENT FOR SIZE GROUP I AT
C                    WAVELENGTH J FOR CARBON PARTICLES (CM2/GM)
C      CMUEA(I,J) = MASS EXTINCTION COEFFICIENT FOR SIZE GROUP I AT
C                    WAVELENGTH J FOR MODE A DUST PARTICLES (CM2/GM)
C      CMUEB(I,J) = MASS EXTINCTION COEFFICIENT FOR SIZE GROUP I AT
C                    WAVELENGTH J FOR MODE B DUST PARTICLES (CM2/GM)
C      CMUEC(I,J) = MASS EXTINCTION COEFFICIENT FOR SIZE GROUP I AT
C                    WAVELENGTH J FOR CARBON PARTICLES (CM2/GM)
C      CMUBA(I,J) = MASS BACKSCATTER COEFFICIENT FOR SIZE GROUP I AT
C                    WAVELENGTH J FOR MODE A DUST PARTICLES (CM2/GM)
C      CMUBB(I,J) = MASS BACKSCATTER COEFFICIENT FOR SIZE GROUP I AT
C                    WAVELENGTH J FOR MODE B DUST PARTICLES (CM2/GM)
C      CMUBC(I,J) = MASS BACKSCATTER COEFFICIENT FOR SIZE GROUP I AT
C                    WAVELENGTH J FOR CARBON PARTICLES (CM2/GM)
C      CMUEMA(IRT) = MEAN MASS EXTINCTION COEFFICIENT FOR THE ENTIRE MODE
C                     A PARTICLE DISTRIBUTION AT WAVELENGTH IRT (CM2/GM)
C      CMUEMB(IRT) = MEAN MASS EXTINCTION COEFFICIENT FOR THE ENTIRE MODE
C                     B PARTICLE DISTRIBUTION AT WAVELENGTH IRT (CM2/GM)
C      CMUEMC(IRT) = MEAN MASS EXTINCTION COEFFICIENT FOR THE ENTIRE
C                     CARBON PARTICLE DISTRIBUTION AT WAVELENGTH IRT
C                     (CM2/GM)
C      CMUSMA(IRT) = MEAN MASS SCATTERING COEFFICIENT FOR THE ENTIRE MODE
C                     A PARTICLE DISTRIBUTION AT WAVELENGTH IRT (CM2/GM)
C      CMUSMB(IRT) = MEAN MASS SCATTERING COEFFICIENT FOR THE ENTIRE MODE
C                     B PARTICLE DISTRIBUTION AT WAVELENGTH IRT (CM2/GM)
C      CMUSMC(IRT) = MEAN MASS SCATTERING COEFFICIENT FOR THE ENTIRE
C                     CARBON PARTICLE DISTRIBUTION AT WAVELENGTH IRT
C                     (CM2/GM)
C      CMUBMA(IRT) = MEAN MASS BACKSCATTER COEFFICIENT FOR THE ENTIRE
C                     A PARTICLE DISTRIBUTION AT WAVELENGTH IRT (CM2/GM)
C      CMUBMB(IRT) = MEAN MASS BACKSCATTER COEFFICIENT FOR THE ENTIRE
C                     B PARTICLE DISTRIBUTION AT WAVELENGTH IRT (CM2/GM)
C      CMUBMC(IRT) = MEAN MASS BACKSCATTER COEFFICIENT FOR THE ENTIRE
C                     CARBON PARTICLE DISTRIBUTION AT WAVELENGTH IRT
C                     (CM2/GM)
C
C      NOTE THAT THE MASS ABSORPTION COEFFICIENTS AND ALL AVERAGE CROSS
C      SECTIONS ARE NOT CARRIED EXPLICITLY BUT ARE CALCULATED WHEN NEEDED
C      BY   CMUAA(I,J) = CMUEA(I,J) - CMUSA(I,J)
C           SIGAA(I,J) = CMUAA(I,J) / PNGA(I)
C      WITH SIMILAR RELATIONS FOR THE B AND C MATERIALS AND THE OTHER
C      AVERAGE CROSS SECTIONS
C
C
       COMMON / CCGRP / MGRP, MSIZE, MSPHER, DLOW, DHIGH, DM, S, DMIN,
      1                 DMAX, P,  XR, XI, RHO, PNG, FN, FM, SIGA, SIGS,
      2                 SIGE, SIGB, SPN(21), CMUA, CMUS, CMUE, CMUB, WL
       COMMON / CINPT2 / FREQ(10), XLAMDA(10), XT(10), YT(10), ZT(10),
      1                   RX(10), YR(10), ZR(10)
```

```
      COMMON / CINPT3 / XNAR(10), XNAI(10), XNBR(10), XNBI(10), XNCR(10)
     1                , XNCI(10), AMA, SA, AMINA, AMAXA, PA, AMB, SB,
     2                  AMINB, AMAXB, PB, AMC, SC, AMINC, AMAXC, PC
      COMMON / CINPT4 / RHOG, RHOD, RHOC, FH2 , XLC, RMAB, RBASE
      COMMON / CINPT6 / NR, NOG, NRT, NTIME, NPROB, IPRINT
      COMMON / CINPT7 / DGROUP(50), TIME(25)
      COMMON / CPGRP / FNA(50), FNB(50), FNC(50), FMA(50), FMB(50),
     1                 FMC(50), PNGA(50), PNGB(50), PNGC(50),
     2                 CMUSA(50,10), CMUSB(50,10), CMUSC(50,10),
     3                 CMUEA(50,10), CMUEB(50,10), CMUEC(50,10),
     4                 CMUBA(50,10), CMUBB(50,10), CMUBC(50,10)
      COMMON / TAPE / IIAPE, JTAPE
      DIMENSION ISKIP(10)
      DIMENSION CMUEMA(10), CMUEMB(10), CMUEMC(10), CMUSMA(10),
     1          CMUSMB(10), CMUSMC(10), CMUBMA(10), CMUBMB(10),
     2          CMUBMC(10), FMO(50), PMASSF(50)
C
C     SET FRACTIONALIZATION PARAMETER
      DATA FRZT   0.5 
C
C     ZERO OUT THE FREQUENCY CALCULATION CONTROL INDEX
C     ZERO OUT THE MEAN MASS COEFFICIENTS FOR THE THREE MATERIALS
      DO 5 IRT = 1, NRT
      ISKIP(IRT) = 0
      CMUEMA(IRT) = 0.
      CMUEMB(IRT) = 0.
      CMUEMC(IRT) = 0.
      CMUSMA(IRT) = 0.
      CMUSMB(IRT) = 0.
      CMUSMC(IRT) = 0.
      CMUBMA(IRT) = 0.
      CMUBMB(IRT) = 0.
      CMUBMC(IRT) = 0.
    5 CONTINUE
C
C     ZERO OUT NUMBER AND MASS FRACTION PARAMETERS
      DO 6 IDG = 1, NDG
      FNA(IDG) = 0.
      FNB(IDG) = 0.
      FNC(IDG) = 0.
      FMA(IDG) = 0.
      FMB(IDG) = 0.
      FMC(IDG) = 0.
    6 CONTINUE
C
C     LOOP OVER THE MATERIALS
      DO 175 IMAT = 1, 3
C
C     SET CONTROL VARIABLES AND INPUT PARAMETERS
    7 GO TO( 8, 10, 20 ), IMAT
C
C     IMAT = 1 THE MATERIAL IS MODE A DUST PARTICLES
    8 MLN = 0
      MPL = 0
      IF( AMA * SA .GT. 0. ) MLN = -1
      IF( AMINA * AMAXA * PA .GT. 0. ) MPL = -2
      MSIZE = MLN + MPL
      MSPHER = 1
```

```
      RHO = RHOD
      DM = 1.E-4 * AMA
      S = SA
      DMIN = 1.E-4 * AMINA
      DMAX = 1.E-4 * AMAXA
      P = PA
      GO TO 30
C
C     IMAT = 2 THE MATERIAL IS MODE B DUST PARTICLES
   10 MLN = 0
      MPL = 0
      IF( AMB * SB .GT. 0. ) MLN = -1
      IF( AMINB * AMAXB * PB .GT. 0. ) MPL = -2
      MSIZE = MLN + MPL
      MSPHER = 1
      RHO = RHOD
      DM = 1.E-4 * AMB
      S = SB
      DMIN = 1.E-4 * AMINB
      DMAX = 1.E-4 * AMAXB
      P = PB
      GO TO 30
C
C     IMAT = 3 THE MATERIAL IS CARBON PARTICLES
   20 MLN = 0
      MPL = 0
      IF( AMC * SC .GT. 0. ) MLN = -1
      IF( AMINC * AMAXC * PC .GT. 0. ) MPL = -2
      MSIZE = MLN + MPL
      MSPHER = 1
      RHO = RHOC
      DM = 1.E-4 * AMC
      S = SC
      DMIN = 1.E-4 * AMINC
      DMAX = 1.E-4 * AMAXC
      P = PC
C
C     FOR THIS MATERIAL LOOP OVER WAVELENGTHS
   30 DO 170 IRT = 1, NRT
C
C     CHECK IF THIS FREQUENCY IS THE SAME AS A PREVIOUSLY CALCULATED
C     FREQUENCY
      IF( IRT .EQ. 1 ) GO TO 38
      IF( ISKIP(IRT) .GT. 0 ) GO TO 33
      IRT1 = IRT - 1
      DO 31 IRTC = 1, IRT1
      IRTP = IRTC
      IF( XLAMDA(IRT) .EQ. XLAMDA(IRTC) ) GO TO 32
   31 CONTINUE
      GO TO 38
C
C     FREQUENCY HAS BEEN CALCULATED PREVIOUSLY, USE PREVIOUS RESULTS
   32 ISKIP(IRT) = IRTP
   33 IRTP = ISKIP(IRT)
      DO 37 IDG = 1, NDG
      GO TO( 34, 35, 36 ), IMAT
   34 CMUEA(IDG,IRT) = CMUEA(IDG,IRTP)
      CMUSA(IDG,IRT) = CMUSA(IDG,IRTP)
```

```
      CMUBA(IDG,IRT) = CMUBA(IDG,IRTP)
      CMUEMA(IRT) = CMUEMA(IRTP)
      CMUSMA(IRT) = CMUSMA(IRTP)
      CMUBMA(IRT) = CMUBMA(IRTP)
      GO TO 37
   35 CMUEB(IDG,IRT) = CMUEB(IDG,IRTP)
      CMUSB(IDG,IRT) = CMUSB(IDG,IRTP)
      CMUBB(IDG,IRT) = CMUBB(IDG,IRTP)
      CMUEMB(IRT) = CMUEMB(IRTP)
      CMUSMB(IRT) = CMUSMB(IRTP)
      CMUBMB(IRT) = CMUBMB(IRTP)
      GO TO 37
   36 CMUEC(IDG,IRT) = CMUEC(IDG,IRTP)
      CMUSC(IDG,IRT) = CMUSC(IDG,IRTP)
      CMUBC(IDG,IRT) = CMUBC(IDG,IRTP)
      CMUEMC(IRT) = CMUEMC(IRTP)
      CMUSMC(IRT) = CMUSMC(IRTP)
      CMUBMC(IRT) = CMUBMC(IRTP)
   37 CONTINUE
      GO TO 170
C
C     FREQUENCY HAS NOT BEEN CALCULATED PREVIOUSLY, DO CALCULATIONS
C
C     SET WAVELENGTH FOR CCGRP COMMON
   38 WL = 1.E-4 * XLAMDA(IRT)
C
C     SET SIZE GROUP CALCULATION INDICATOR
C     INITIALIZE THE MAXIMUM GROUP EXTINCTION CONTRIBUTION
      ICALC = 1
      EMAX = 0.
C
C     SET INDICIES OF REFRACTION
      GO TO( 40, 50, 60 ), IMAT
   40 XR = XNAR(IRT)
      XI = XNAI(IRT)
      GO TO 70
   50 XR = XNBR(IRT)
      XI = XNBI(IRT)
      GO TO 70
   60 XR = XNCR(IRT)
      XI = XNCI(IRT)
   70 CONTINUE
C
C     LOOP OVER SIZE GROUPS, START WITH THE SMALLEST SIZE GROUP, STOP
C     GROUP CALCULATIONS WHEN EXTINCTION CONTRIBUTION FROM LAST GROUP IS
C     LESS THAN 1.E-6 OF MAXIMUM GROUP EXTINCTION CONTRIBUTION
      DO 160 IDG = 1, NDG
C
C     CHECK IF EXTINCTION CONTRIBUTIONS FROM THE SIZE GROUPS HAVE
C     BECOME NEGLIGIBLE
      IF( ICALC .EQ. 0 ) GO TO 150
C
C     SET GROUP NUMBER FOR CCGRP COMMON
      NGRP = IDG
C
C     SET THE SIZE LIMITS FOR THIS SIZE GROUP
      IF( IDG .EQ. 1 ) GO TO 80
      DLOW = 1.E-4 * DGROUP(IDG - 1)
```

```
      DHIGH = 1.E-4 * DGROUP(IDG)
      GO TO 90
   80 DLOW = 0.
      DHIGH = 1.E-4 * DGROUP(1)
   90 IF( DHIGH .LE. 0. ) GO TO 160
C
C     CALCULATE THE PROPAGATION PARAMETERS FOR THIS SIZE GROUP,
C     WAVELENGTH, AND MATERIAL
      CALL CGROUP
C
C     SET THE PROPAGATION PARAMETERS
  154 GO TO( 156, 157, 158 ), IMAT
C
  156 IF( FNA(IDG) .LE. 0. ) FNA(IDG) = FN
      IF( FMA(IDG) .LE. 0. ) FMA(IDG) = FM
      PNGA(IDG) = PNG
      CHUSA(IDG,IRT) = CHUS
      CHUEA(IDG,IRT) = CHUE
      CHUBA(IDG,IRT) = CHUB
      CHUEMA(IRT) = CHUEMA(IRT) + FMA(IDG) * CHUEA(IDG,IRT)
      CHUSMA(IRT) = CHUSMA(IRT) + FMA(IDG) * CHUSA(IDG,IRT)
      CHUBMA(IRT) = CHUBMA(IRT) + FMA(IDG) * CHUBA(IDG,IRT)
      GO TO 159
C
  157 IF( FNB(IDG) .LE. 0. ) FNB(IDG) = FN
      IF( FMB(IDG) .LE. 0. ) FMB(IDG) = FM
      PNGB(IDG) = PNG
      CHUSB(IDG,IRT) = CHUS
      CHUEB(IDG,IRT) = CHUE
      CHUBB(IDG,IRT) = CHUB
      CHUEMB(IRT) = CHUEMB(IRT) + FMB(IDG) * CHUEB(IDG,IRT)
      CHUSMB(IRT) = CHUSMB(IRT) + FMB(IDG) * CHUSB(IDG,IRT)
      CHUBMB(IRT) = CHUBMB(IRT) + FMB(IDG) * CHUBB(IDG,IRT)
      GO TO 159
C
  158 IF( FNC(IDG) .LE. 0. ) FNC(IDG) = FN
      IF( FMC(IDG) .LE. 0. ) FMC(IDG) = FM
      PNGC(IDG) = PNG
      CHUSC(IDG,IRT) = CHUS
      CHUEC(IDG,IRT) = CHUE
      CHUBC(IDG,IRT) = CHUB
      CHUEMC(IRT) = CHUEMC(IRT) + FMC(IDG) * CHUEC(IDG,IRT)
      CHUSMC(IRT) = CHUSMC(IRT) + FMC(IDG) * CHUSC(IDG,IRT)
      CHUBMC(IRT) = CHUBMC(IRT) + FMC(IDG) * CHUBC(IDG,IRT)
C
C     SET MAXIMUM VALUE OF EXTINCTION CONTRIBUTION
  159 EMAX = AMAX1( EMAX, FM * CHUE )
      IF( EMAX .LE. 0. ) GO TO 160
C
C     CHECK IF EXTINCTION CONTRIBUTION IS NEGLIGIBLE
      IF( FM * CHUE .GT. 1.E-6 * EMAX ) GO TO 160
C
C     EXTINCTION CONTRIBUTION HAS BECOME NEGLIGIBLE, SET CONTROL
C     PARAMETER TO SKIP REST OF CROSS SECTION CALCULATIONS
      ICALC = 0
      FN = 0.
      FM = 0.
      PNG = 0.
```

```
      CHUS = 0.
      CHUE = 0.
      CHUB = 0.
C
  160 CONTINUE
C
  170 CONTINUE
C
  175 CONTINUE
C
C
C     WRITE OUT THE SIZE DISTRIBUTION PROPAGATION PARAMETERS FOR THIS
C     PROBLEM
C
  180 DO 300 IMAT = 1, 3
C
      DO 290 IRT = 1, NRT
C
C     CHECK IF THIS FREQUENCY IS THE SAME AS A PREVIOUS FREQUENCY
C     IF SO SKIP REPRINTING THE PROPAGATION PARAMETERS
      IF( ISKIP(IRT) .GT. 0 ) GO TO 290
C
C     SET PRINT LINE COUNTER
      ILINES = 13
C
      WRITE(JTAPE, 190) NPROB
  190 FORMAT(1H1,74H                                          ASL MUN
     1ITION DUST CLOUD MODEL / /
     21H0,78H                                PROPAGATION CONSTANTS
     3 FOR PROBLEM NUMBER , I3 /
     41H ,84H                                ( SIZE DISTRIBUTION O
     5NLY, NO FRACTIONIZATION ) )
C
      GO TO( 200, 210, 220 ), IMAT
C
  200 WRITE(JTAPE, 202)
  202 FORMAT(1H0,70H                                         DUST
     1PARTICLES - MODE A )
      GO TO 230
  210 WRITE(JTAPE, 212)
  212 FORMAT(1H0,70H                                         DUST
     1PARTICLES - MODE B )
      GO TO 230
  220 WRITE(JTAPE, 225)
  225 FORMAT(1H0,66H                                           CA
     1RBON PARTICLES )
C
  230 WRITE(JTAPE, 235) XLAMDA(IRT), FREQ(IRT)
  235 FORMAT(1H0, 46H                          WAVELENGTH = ,
     1 F7.1, 21H MICRONS (FREQUENCY = , 1PE9.2, 5H GHZ) / 1H0,
     2114HSIZE    MAXIMUM    NUMBER OF      NUMBER FRACTION   MASS FRACTI
     3ON    GROUP MASS COEFFICIENTS ( FIRST LINE, CM2/GM ) / 1H ,
     4120HGROUP  DIAMETER   PARTICLES PER  (NUMBER IN GROUP  (MASS IN GR
     5OUP   AVERAGE CROSS SECTIONS ( SECOND LINE, CM2/PARTICLE ) / 1H ,
     6121H       (MICRONS)    GRAM IN GROUP   /TOTAL NUMBER)    /TOTAL MAS
     7S)     EXTINCTION    ABSORPTION    SCATTERING   BACKSCATTER )
C
      DO 280 IDG = 1, NDG
```

```
C
      GO TO( 240, 260, 270 ), IMAT
  240 IF( CHUEA(IDG,IRT) .EQ. 0. ) GO TO 280
      CHUAA = CHUEA(IDG,IRT) - CHUSA(IDG,IRT)
      SIGEA = CHUEA(IDG,IRT) / PNGA(IDG)
      SIGAA = CHUAA / PNGA(IDG)
      SIGSA = CHUSA(IDG,IRT) / PNGA(IDG)
      SIGBA = CHUBA(IDG,IRT) / PNGA(IDG)
      WRITE(JTAPE, 250) IDG, DGROUP(IDG), PNGA(IDG), FNA(IDG), FMA(IDG),
     1                    CHUEA(IDG,IRT), CHUAA, CHUSA(IDG,IRT),
     2                    CHUBA(IDG,IRT), SIGEA, SIGAA, SIGSA, SIGBA
  250 FORMAT(1H0, I3, F11.1, 1PE15.3, 2E17.3, E15.3, 3E14.3 /
     11H ,63X, 1PE15.3, 3E14.3 )
      GO TO 277
C
  260 IF( CHUEB(IDG,IRT) .EQ. 0. ) GO TO 280
      CHUAB = CHUEB(IDG,IRT) - CHUSB(IDG,IRT)
      SIGEB = CHUEB(IDG,IRT) / PNGB(IDG)
      SIGAB = CHUAB / PNGB(IDG)
      SIGSB = CHUSB(IDG,IRT) / PNGB(IDG)
      SIGBB = CHUBB(IDG,IRT) / PNGB(IDG)
      WRITE(JTAPE, 265) IDG, DGROUP(IDG), PNGB(IDG), FNB(IDG), FMB(IDG),
     1                    CHUEB(IDG,IRT), CHUAB, CHUSB(IDG,IRT),
     2                    CHUBB(IDG,IRT), SIGEB, SIGAB, SIGSB, SIGBB
  265 FORMAT(1H0, I3, F11.1, 1PE15.3, 2E17.3, E15.3, 3E14.3 /
     11H ,63X, 1PE15.3, 3E14.3 )
      GO TO 277
C
  270 IF( CHUEC(IDG,IRT) .EQ. 0. ) GO TO 280
      CHUAC = CHUEC(IDG,IRT) - CHUSC(IDG,IRT)
      SIGEC = CHUEC(IDG,IRT) / PNGC(IDG)
      SIGAC = CHUAC / PNGC(IDG)
      SIGSC = CHUSC(IDG,IRT) / PNGC(IDG)
      SIGBC = CHUBC(IDG,IRT) / PNGC(IDG)
      WRITE(JTAPE, 275) IDG, DGROUP(IDG), PNGC(IDG), FNC(IDG), FMC(IDG),
     1                    CHUEC(IDG,IRT), CHUAC, CHUSC(IDG,IRT),
     2                    CHUBC(IDG,IRT), SIGEC, SIGAC, SIGSC, SIGBC
  275 FORMAT(1H0, I3, F11.1, 1PE15.3, 2E17.3, E15.3, 3E14.3 /
     11H ,63X, 1PE15.3, 3E14.3 )
C
  277 ILINES = ILINES + 3
      IF( ILINES .LT. 50 ) GO TO 280
      ILINES = 7
      WRITE(JTAPE, 278 ) NPROB
  278 FORMAT(1H1,73H                                   PROPAGATION CONSTANT
     1S FOR PROBLEM NUMBER , I3, 12H (CONTINUED) / / 1H0,
     2114HSIZE   MAXIMUM    NUMBER OF       NUMBER FRACTION   MASS FRACTI
     3ON    GROUP MASS COEFFICIENTS ( FIRST LINE, CM2/GM ) / 1H ,
     4120HGROUP  DIAMETER   PARTICLES PER  (NUMBER IN GROUP  (MASS IN GR
     5OUP   AVERAGE CROSS SECTIONS ( SECOND LINE, CM2/PARTICLE ) / 1H ,
     6121H        (MICRONS)  GRAM IN GROUP   /TOTAL NUMBER)    /TOTAL MAS
     7S)     EXTINCTION    ABSORPTION    SCATTERING   BACKSCATTER )
C
  280 CONTINUE
C
      GO TO( 281, 283, 285 ), IMAT
  281 CHUAMA = CHUEMA(IRT) - CHUSMA(IRT)
      WRITE(JTAPE, 282) CHUEMA(IRT), CHUAMA, CHUSMA(IRT), CHUBMA(IRT)
```

```
  282 FORMAT( 1H0, 9H   ENTIRE, 55X, 1P4E14.3/ 1H , 12HDISTRIBUTION )
      GO TO 290
  283 CMUAMB = CMUEMB(IRT) - CMUSMB(IRT)
      WRITE(JTAPE, 284) CMUEMB(IRT), CMUAMB, CMUSMB(IRT), CMUBMB(IRT)
  284 FORMAT( 1H0, 9H   ENTIRE, 55X, 1P4E14.3/ 1H , 12HDISTRIBUTION )
      GO TO 290
  285 CMUAMC = CMUEMC(IRT) - CMUSMC(IRT)
      WRITE(JTAPE, 286) CMUEMC(IRT), CMUAMC, CMUSMC(IRT), CMUBMC(IRT)
  286 FORMAT( 1H0, 9H   ENTIRE, 55X, 1P4E14.3/ 1H , 12HDISTRIBUTION )
C
  290 CONTINUE
C
  300 CONTINUE
C
C
C     FRACTIONIZATION SECTION
C     THIS SECTION REDEFINES THE MASS FRACTIONS AND CROSS SECTIONS IN
C     EACH SIZE GROUP FOR EACH MATERIAL TO ACCOUNT FOR THE EFFECTS OF
C     FRACTIONIZATION
C
C     LOOP OVER THE MATERIALS
      DO 610 IMAT = 1, 3
C
C     SET THE SIZE DISTRIBUTION MASS FRACTIONS FOR THIS MATERIAL
      GO TO ( 400, 420, 440 ), IMAT
C
C     DUST - MODE A
  400 DO 410 IDG = 1, NDG
      FMD(IDG) = FMA(IDG)
  410 CONTINUE
      GO TO 460
C
C     DUST - MODE B
  420 DO 430 IDG = 1, NDG
      FMD(IDG) = FMB(IDG)
  430 CONTINUE
      GO TO 460
C
C     CARBON
  440 DO 450 IDG = 1, NDG
      FMD(IDG) = FMC(IDG)
  450 CONTINUE
C
C     CALCULATE THE PARTIAL MASS FRACTIONS ( MASS OF MATERIAL IN THE IDG
C     SIZE GROUP DIVIDED BY THE SUM OF MASSES IN ALL GROUPS LARGER THAN
C     THE IDG SIZE GROUP )
  460 PMASSF(NDG) = 0.
      SUMASS = 0.
      DO 470 LDG = 2, NDG
      IDG = NDG + 1 - LDG
      SUMASS = SUMASS + FMD(IDG + 1)
      PMASSF(IDG) = 0.
      IF( SUMASS .GT. 0. ) PMASSF(IDG) = FMD(IDG) / SUMASS
  470 CONTINUE
C
C     CALCULATE THE NEW MASS FRACTION FOR EACH SIZE GROUP
      SUMPMF = 0.
      DO 520 IDG = 1, NDG
```

```
      FRZT1 = 1.
      IF( IDG .EQ. NDG ) GO TO 475
      IF( FMD(IDG + 1) .GT. 0. ) FRZT1 = 1. - FRZT
  475 GO TO ( 480, 490, 500 ), IMAT
  480 FMA(IDG) = FMA(IDG) + ( FRZT1 + FRZT * SUMPMF )
      GO TO 510
  490 FMB(IDG) = FMB(IDG) + ( FRZT1 + FRZT * SUMPMF )
      GO TO 510
  500 FMC(IDG) = FMC(IDG) + ( FRZT1 + FRZT * SUMPMF )
  510 SUMPMF = SUMPMF + PMASSF(IDG)
  520 CONTINUE
C
C     CALCULATE THE CROSS SECTIONS FOR EACH SIZE GROUP FOR EACH
C     FREQUENCY
C     LOOP OVER THE FREQUENCIES
      DO 605 IRT = 1, NRT
C
C     CHECK IF THIS FREQUENCY IS THE SAME AS A PREVIOUS FREQUENCY
      IF( ISKIP(IRT) .LE. 0 ) GO TO 565
C
C     FREQUENCY IS THE SAME, USE PREVIOUS RESULTS
      IRTP = ISKIP(IRT)
      DO 560 IDG = 1, NDG
      GO TO ( 530, 540, 550 ), IMAT
  530 CMUEA(IDG,IRT) = CMUEA(IDG,IRTP)
      CMUSA(IDG,IRT) = CMUSA(IDG,IRTP)
      CMUBA(IDG,IRT) = CMUBA(IDG,IRTP)
      GO TO 560
  540 CMUEB(IDG,IRT) = CMUEB(IDG,IRTP)
      CMUSB(IDG,IRT) = CMUSB(IDG,IRTP)
      CMUBB(IDG,IRT) = CMUBB(IDG,IRTP)
      GO TO 560
  550 CMUEC(IDG,IRT) = CMUEC(IDG,IRTP)
      CMUSC(IDG,IRT) = CMUSC(IDG,IRTP.
      CMUBC(IDG,IRT) = CMUBC(IDG,IRTP)
  560 CONTINUE
      GO TO 605
C
C     FREQUENCY NOT THE SAME, DO CALCULATIONS
  565 SUME = 0.
      SUMS = 0.
      SUMB = 0.
      DO 600 IDG = 2, NDG
      LDG = IDG - 1
      FRZT1 = 1.
      IF( IDG .EQ. NDG ) GO TO 568
      IF( FMD(IDG + 1) .GT. 0. ) FRZT1 = 1. - FRZT
  568 GO TO ( 570, 580, 590 ), IMAT
  570 SUME = SUME + PMASSF(LDG) * CMUEA(LDG,IRT)
      SUMS = SUMS + PMASSF(LDG) * CMUSA(LDG,IRT)
      SUMB = SUMB + PMASSF(LDG) * CMUBA(LDG,IRT)
      IF( FMA(IDG) .LE. 0. ) GO TO 600
      CMUEA(IDG,IRT) = FMD(IDG) * ( FRZT1 * CMUEA(IDG,IRT)
     1                 + FRZT * SUME ) / FMA(IDG)
      CMUSA(IDG,IRT) = FMD(IDG) * ( FRZT1 * CMUSA(IDG,IRT)
     1                 + FRZT * SUMS ) / FMA(IDG)
      CMUBA(IDG,IRT) = FMD(IDG) * ( FRZT1 * CMUBA(IDG,IRT)
     1                 + FRZT * SUMB ) / FMA(IDG)
```

```
      GO TO 600
  580 SUME = SUME + PHASSF(LDG) * CHUEB(LDG,IRT)
      SUMS = SUMS + PHASSF(LDG) * CHUSB(LDG,IRT)
      SUMB = SUMB + PHASSF(LDG) * CHUBB(LDG,IRT)
      IF( FMB(IDG) .LE. 0. ) GO TO 600
      CHUEB(IDG,IRT) = FMD(IDG) * ( FRZT1 * CHUEB(IDG,IRT)
     1               + FRZT * SUME ) / FMB(IDG)
      CHUSB(IDG,IRT) = FMD(IDG) * ( FRZT1 * CHUSB(IDG,IRT)
     1               + FRZT * SUMS ) / FMB(IDG)
      CHUBB(IDG,IRT) = FMD(IDG) * ( FRZT1 * CHUBB(IDG,IRT)
     1               + FRZT * SUMB ) / FMB(IDG)
      GO TO 600
  590 SUME = SUME + PHASSF(LDG) * CHUEC(LDG,IRT)
      SUMS = SUMS + PHASSF(LDG) * CHUSC(LDG,IRT)
      SUMB = SUMB + PHASSF(LDG) * CHUBC(LDG,IRT)
      IF( FMC(IDG) .LE. 0. ) GO TO 600
      CHUEC(IDG,IRT) = FMD(IDG) * ( FRZT1 * CHUEC(IDG,IRT)
     1               + FRZT * SUME ) / FMC(IDG)
      CHUSC(IDG,IRT) = FMD(IDG) * ( FRZT1 * CHUSC(IDG,IRT)
     1               + FRZT * SUMS ) / FMC(IDG)
      CHUBC(IDG,IRT) = FMD(IDG) * ( FRZT1 * CHUBC(IDG,IRT)
     1               + FRZT * SUMB ) / FMC(IDG)
C
  600 CONTINUE
C
  605 CONTINUE
C
  610 CONTINUE
C
C     WRITE OUT THE PROPAGATION PARAMETERS INCLUDING THE EFFECTS OF
C     FRACTIONIZATION
C
      DO 800 IMAT = 1, 3
C
      DO 790 IRT = 1, NST
C
C     CHECK IF THIS FREQUENCY IS THE SAME AS A PREVIOUS FREQUENCY
C     IF SO SKIP REPRINTING THE PROPAGATION PARAMETERS
      IF( ISKIP(IRT) .GT. 0 ) GO TO 790
C
C     SET PRINT LINE COUNTER
      ILINES = 13
C
      WRITE(JTAPE, 615) NPROB
  615 FORMAT(1H1,70H                                                ASL MUN
     1ITION DUST CLOUD MODEL / /
     21H0,70H                                      PROPAGATION CONSTANTS
     3 FOR PROBLEM NUMBER , I3 /
     41H , 73H                                    ( FRACTIONIZATION EFF
     5ECTS INCLUDED ) )
C
      GO TO ( 620, 640, 660 ), IMAT
C
  620 WRITE(JTAPE, 630)
  630 FORMAT(1H0,70H                                                DUST
     1PARTICLES - MODE A )
      GO TO 680
  640 WRITE(JTAPE, 650)
```

```
      650 FORMAT(1H0,70H                                                DUST
         1PARTICLES - MODE B )
          GO TO 680
      660 WRITE(JTAPE, 670)
      670 FORMAT(1H0,66H                                                    CA
         1RBON PARTICLES )
C
      680 WRITE(JTAPE, 690) XLAMDA(IRT), FREQ(IRT)
      690 FORMAT(1H0, 46H                                     WAVELENGTH = ,
         1 F7.1, 21H MICRONS (FREQUENCY = , 1PE9.2, 5H GHZ) / 1H0,
         2 76HSIZE   MAXIMUM   MASS FRACTION            GROUP MASS COEFFICIE
         3NTS ( CM2/GM ) / 1H ,
         4 86HGROUP  DIAMETER  (MASS IN GROUP  EXTINCTION    ABSORPTION    S
         5CATTERING    BACKSCATTER /
         6 30H        (MICRONS)  /TOTAL MASS) / 1H  )
C
          DO 780 IDG = 1, NDG
C
          GO TO ( 700, 720, 740 ), IMAT
  700 IF( CMUEA(IDG,IRT) .EQ. 0. ) GO TO 780
          CMUAA = CMUEA(IDG,IRT) - CMUSA(IDG,IRT)
          WRITE(JTAPE, 710) IDG, DGROUP(IDG), FMA(IDG), CMUEA(IDG,IRT),
         1                      CMUAA, CMUSA(IDG,IRT), CMUBA(IDG,IRT)
  710 FORMAT(1H , I3, F11.1, 1PE13.3, 2X, 4E14.3 )
          GO TO 760
C
  720 IF( CMUEB(IDG,IRT) .EQ. 0. ) GO TO 780
          CMUAB = CMUEB(IDG,IRT) - CMUSB(IDG,IRT)
          WRITE(JTAPE, 730) IDG, DGROUP(IDG), FMB(IDG), CMUEB(IDG,IRT),
         1                      CMUAB, CMUSB(IDG,IRT), CMUBB(IDG,IRT)
  730 FORMAT(1H , I3, F11.1, 1PE13.3, 2X, 4E14.3 )
          GO TO 760
C
  740 IF( CMUEC(IDG,IRT) .EQ. 0. ) GO TO 780
          CMUAC = CMUEC(IDG,IRT) - CMUSC(IDG,IRT)
          WRITE(JTAPE, 750) IDG, DGROUP(IDG), FMC(IDG), CMUEC(IDG,IRT),
         1                      CMUAC, CMUSC(IDG,IRT), CMUBC(IDG,IRT)
  750 FORMAT(1H , I3, F11.1, 1PE13.3, 2X, 4E14.3 )
C
  760 ILINES = ILINES + 1
          IF( ILINES .LT. 50 ) GO TO 780
          ILINES = 7
          WRITE(JTAPE, 770 ) NPROB
  770 FORMAT(1H1,73H                                    PROPAGATION CONSTANT
         1S FOR PROBLEM NUMBER , I3, 12H (CONTINUED) / / 1H0,
         2 76HSIZE   MAXIMUM   MASS FRACTION            GROUP MASS COEFFICIE
         3NTS ( CM2/GM ) / 1H ,
         4 86HGROUP  DIAMETER  (MASS IN GROUP  EXTINCTION    ABSORPTION    S
         5CATTERING    BACKSCATTER /
         6 30H        (MICRONS)  /TOTAL MASS) / 1H0 )
C
  780 CONTINUE
C
  790 CONTINUE
C
  800 CONTINUE
C
          RETURN
C
          END
```

```
      SUBROUTINE CGROUP
C
C     THIS SUBROUTINE CALCULATES THE SCATTERING AND
C     EXTINCTION PARAMETERS FOR A GIVEN SIZE GROUP. THE RANGE OF
C     PARTICLE SIZES IN THE SIZE GROUP CAN BE ONLY A SMALL SUBSET OF THE
C     WHOLE PARTICLE DISTRIBUTION RANGE OR CAN INCLUDE THE WHOLE
C     DISTRIBUTION. THREE TYPES OF PARTICLE SIZE PROBABILITY
C     DISTRIBUTIONS ARE ALLOWED - LOG NORMAL, POWER LAW, OR HYBRID( A
C     LOG NORMAL JOINED TO A POWER LAW )
C
C     INPUT VARIABLES FROM CCGRP COMMON
C     NGRP   = NUMBER OF THE GIVEN SIZE GROUP
C     MSIZE  =  1 THE PARTICLE SIZE DISTRIBUTION IS LOG NORMAL
C                 COMPUTE PARAMETERS INCLUDING SCATTERING PATTERN
C            = -1 THE PARTICLE SIZE DISTRIBUTION IS LOG NORMAL
C                 COMPUTE PARAMETERS ( NO SCATTERING PATTERN )
C            =  2 THE PARTICLE SIZE DISTRIBUTION IS POWER LAW
C                 COMPUTE PARAMETERS INCLUDING SCATTERING PATTERN
C            = -2 THE PARTICLE SIZE DISTRIBUTION IS POWER LAW
C                 COMPUTE PARAMETERS ( NO SCATTERING PATTERN )
C            =  3 THE PARTICLE SIZE DISTRIBUTION IS HYBRID
C                 COMPUTE PARAMETERS INCLUDING SCATTERING PATTERN
C            = -3 THE PARTICLE SIZE DISTRIBUTION IS HYBRID
C                 COMPUTE PARAMETERS ( NO SCATTERING PATTERN )
C     MSPHER  = 1 THE PARTICLES ARE SPHERICAL, USE STANDARD MIE THEORY
C             = 2 THE PARTICLES ARE NONSPHERICAL, USE MODIFIED MIE
C                 THEORY
C     DLOW    = LOWER LIMIT OF PARTICLE DIAMETER RANGE ( CM )
C     DHIGH   = UPPER LIMIT OF PARTICLE DIAMETER RANGE ( CM )
C     DM     = MEAN DIAMETER PARAMETER FOR LOG NORMAL AND HYBRID
C              DISTRIBUTIONS ( CM )
C     S        STANDARD DEVIATION PARAMETER FOR LOG NORMAL AND HYBRID
C              DISTRIBUTIONS
C     DMIN   = MINIMUM PARTICLE DIAMETER FOR POWER LAW AND POINT AT
C              WHICH LOG NORMAL AND POWER LAW JOIN IN HYBRID
C              DISTRIBUTION ( CM )
C     DMAX   = MAXIMUM PARTICLE DIAMETER FOR POWER LAW AND HYBRID
C              DISTRIBUTIONS ( CM )
C     P      = POWER LAW EXPONENT FOR THE POWER LAW AND HYBRID
C              PROBABILITY DISTRIBUTIONS
C     WL      = WAVELENGTH OF THE INCIDENT RADIATION ( CM )
C     XR      = REAL PART OF THE COMPLEX INDEX OF REFRACTION OF THE
C               PARTICLES
C     XI      = IMAGINARY PART OF THE COMPLEX INDEX OF REFRACTION OF THE
C               PARTICLES ( THE INDEX IS M = XR - I*XI SO THAT BOTH XR
C               AND XI ARE POSITIVE )
C     RHO    = DENSITY OF THE PARTICLES ( GM/CM3 )
C
C     CALCULATED PARAMETERS, OUTPUTS TO CCGRP COMMON
C     PNG    = NUMBER OF PARTICLES PER GRAM ( OF MATERIAL IN THE SIZE
C              GROUP )
C     FN     = NUMBER FRACTION OF PARTICLES IN SIZE GROUP ( RATIO OF
C              NUMBER OF PARTICLES IN SIZE GROUP TO TOTAL NUMBER OF
C              PARTICLES IN DISTRIBUTION )
C     FM     = MASS FRACTION ( RATIO OF MASS OF PARTICLES IN SIZE
C              GROUP TO TOTAL MASS IN DISTRIBUTION )
C     SIGA    = AVERAGE ABSORPTION CROSS SECTION PER PARTICLE
C               IN THE GROUP ( CM2 )
```

```
C      SIGS    = AVERAGE SCATTERING CROSS SECTION PER PARTICLE
C                IN THE GROUP ( CM2 )
C      SIGE    = AVERAGE EXTINCTION CROSS SECTION PER PARTICLE
C                IN THE GROUP ( CM2 )
C      SIGB    = AVERAGE BACKSCATTER CROSS SECTION PER PARTICLE
C                IN THE GROUP ( CM2 )
C      SPN     = NORMALIZED SCATTERING PATTERN FOR THE PARTICLES IN THE
C                GIVEN SIZE RANGE DLOW TO DHIGH. SPN(J) = SCATTERING
C                FUNCTION AT THE SCATTERING ANGLE WHOSE COSINE IS
C                0.1*(J-11), SPN IS NORMALIZED SO THAT THE INTEGRAL OF
C                SPN OVER 4 PI STERADIANS EQUALS 4 PI ( IE, AN ISOTROPIC
C                SCATTERING PATTERN HAS SPN(J) = 1.0 FOR ALL J )
C      CHUA   = MASS ABSORPTION COEFFICIENT ( CM2/GM )
C               WHERE THE GRAM OF MASS PENETRATED REFERS TO THE MASS
C               OF PARTICLES IN THE SIZE GROUP
C      CHUS    = MASS SCATTERING COEFFICIENT ( CM2/GM )
C      CHUE    = MASS EXTINCTION COEFFICIENT ( CM2/GM )
C      CHUB    = MASS BACKSCATTER COEFFICIENT ( CM2/GM )
C      THE MASS COEFFICIENTS ARE CALCULATED BY MULTIPLYING THE AVERAGE
C      CROSS SECTION PER PARTICLE BY THE NUMBER OF PARTICLES PER GRAM
C
C      NOTES
C      THE PROBABILITY DISTRIBUTIONS ARE
C      LOG NORMAL = EXP( -0.5*(LN(D/DM)/LN(S))**2 )/( SQRT(2*PI)*D*LN(S))
C                   WHERE D = PARTICLE DIAMETER ( CM )
C      POWER LAW = (P-1)*D**(-P)/(DMIN**(1-P)-DMAX**(1-P))
C      HYBRID = C1 * LOG NORMAL FOR D BETWEEN 0 AND DMIN
C             = C2 * POWER LAW FOR D BETWEEN DMIN AND DMAX
C             WHERE C1 AND C2 ARE NORMALIZING CONSTANTS WHICH INSURE THAT
C             THE INTEGRAL OVER THE HYBRID PROBABILITY DISTRIBUTION FROM
C             0 TO DMAX EQUALS ONE, AND THAT THE LOG NORMAL AND POWER
C             LAW DISTRIBUTIONS JOIN AT DMIN
C
C
       DIMENSION SPNLN(21), SPNPL(21)
C
C      SET VALUE OF PI
       DATA PI / 3.14159265 /
C
       COMMON / CCGRP / MGRP, MSIZE, MSPHER, DLOW, DHIGH, DM, S, DMIN,
      1                 DMAX, P,  XR, XI, RHO, PNG, FN, FM, SIGA, SIGS,
      2                 SIGE, SIGB, SPN(21), CHUA, CHUS, CHUE, CHUB, WL
C
C      ZERO OUT VARIABLES
       SIGALN = 0.
       SIGSLN = 0.
       SIGELN = 0.
       SIGBLN = 0.
       SIGAPL = 0.
       SIGSPL = 0.
       SIGEPL = 0.
       SIGBPL = 0.
       DO 5 I = 1, 21
       SPNLN( I ) = 0.
       SPNPL( I ) = 0.
     5 CONTINUE
C
```

```
C     DEFAULT VALUES
      IF( MSIZE .EQ. 0 ) GO TO 83
      IF( MSPHER .EQ. 0 ) MSPHER = 1
      IF( RHO .EQ. 0. ) RHO = 2.5
C
C     CHECK THAT GROUP SIZE RANGE IS WITHIN SIZE DISTRIBUTION LIMITS
      IF( WL .LE. 0. ) GO TO 83
      IMSIZE = IABS( MSIZE )
      IF( DLOW .GE. DHIGH ) GO TO 83
      IF( DLOW .LT. 0. ) DLOW = 0.
      IF( IMSIZE .EQ. 1 ) GO TO 84
      IF( IMSIZE .EQ. 2 .AND. DLOW .LT. DMIN ) DLOW = DMIN
      IF( DHIGH .GT. DMAX ) DHIGH = DMAX
      IF( DLOW .LT. DHIGH ) GO TO 84
C
   83 SIGA = 0.
      SIGS = 0.
      SIGE = 0.
      SIGB = 0.
      PNG = 0.
      FN = 0.
      FM = 0.
      GO TO 156
C
C     CHECK WHICH DISTRIBUTION IS TO BE USED
   84 GO TO( 85, 95, 118 ), IMSIZE
C
C
C     DISTRIBUTION IS LOG NORMAL
C     COMPUTE NUMBER AND MASS FRACTIONS
   85 ALNS = ALOG( S )
      SD1 = -1.
      FN1 = 0.
      FM1 = 0.
      SD2 = ALOG( DHIGH / DM ) / ALNS
      SD3 = 3. * ALNS
      IF( DLOW .LE. 0. ) GO TO 90
      SD1 = ALOG( DLOW / DM ) / ALNS
      FN1 = CUMNOR( SD1 )
      FM1 = CUMNOR( SD1 - SD3 )
   90 FN2 = CUMNOR( SD2 )
      FM2 = CUMNOR( SD2 - SD3 )
      IF( SD1 * SD2 .LE. 0. ) GO TO 91
      FN = FN1- FN2
      IF( SD2 .LT. 0. ) FN = - FN
      GO TO 92
   91 FN = 1. - FN1 - FN2
   92 IF( ( SD1 - SD3 ) * ( SD2 - SD3 ) .LE. 0. ) GO TO 93
      FM = FM1 - FM2
      IF( SD2 - SD3 .LT. 0. ) FM = -FM
      GO TO 94
   93 FM = 1. - FM1 - FM2
C
C     COMPUTE AVERAGE CUBED DIAMETER OF GROUP
   94 D3AV = FM * DM**3 * EXP( 9. * ALNS**2 / 2. ) / FN
C
C     COMPUTE CROSS SECTIONS AND SCATTERING PATTERN( FOR POSITIVE MSIZE)
      CALL CROSS( MSIZE, MSPHER, DLOW, DHIGH, DM, S, DUM, WL, XR, XI,
```

```
     1              SIGA, SIGS, SIGE, SIGB, SPN )
      GO TO 155
C
C
C     DISTRIBUTION IS POWER LAW
C     COMPUTE NUMBER AND MASS FRACTION
   95 OMP = 1. - P
      FN = ( DLOW ** OMP - DHIGH ** OMP ) / ( DMIN ** OMP - DMAX ** OMP)
      IF( P .EQ. 4. ) GO TO 100
      FMP = 4. - P
      FM = ( DLOW ** FMP - DHIGH ** FMP ) / ( DMIN ** FMP - DMAX ** FMP)
      GO TO 105
  100 FM = ALOG( DHIGH / DLOW ) / ALOG ( DMAX / DMIN )
C
C     COMPUTE AVERAGE CUBED DIAMETER OF GROUP
  105 CON1 = -OMP / ( DMIN ** OMP - DMAX ** OMP )
      IF( P .EQ. 4. ) GO TO 110
      D3AVT = CON1 * ( DMAX ** FMP - DMIN ** FMP ) / FMP
      GO TO 115
  110 D3AVT = CON1 * ALOG( DMAX / DMIN )
  115 D3AV = D3AVT * FM / FN
C
C     COMPUTE CROSS SECTIONS AND SCATTERING PATTERN( FOR POSITIVE MSIZE)
      CALL CROSS( MSIZE, MSPHER, DLOW, DHIGH, DMIN, DMAX, P, WL, XR, XI,
     1              SIGA, SIGS, SIGE, SIGB, SPN )
      GO TO 155
C
C
C     DISTIBUTION IS HYBRID
C     PRELIMINARY CALCULATIONS, DO ONLY ONCE
C
  118 IF( MGRP .GT. 1 ) GO TO 126
C
C     COMPUTE NORMALIZING CONSTANTS C1 AND C2
      OMP = 1. - P
      PP1 = -OMP * DMIN ** ( -P ) / ( DMIN ** OMP - DMAX ** OMP )
      ALNS = ALOG( S )
      SD1 = ALOG( DMIN / DM ) / ALNS
      PL1 = EXP( -SD1 ** 2 / 2. ) / ( SQRT( 2. * PI ) * DMIN * ALNS )
      CUM = CUMNOR ( SD1 )
      IF( SD1 .GT. 0. ) CUM = 1. - CUM
      C2 = 1. / ( 1. + CUM * PP1 / PL1 )
      C1 = C2 * PP1 / PL1
C
C     CALCULATE THE NUMBER AND MASS FRACTIONS OF THE LOG NORMAL AND
C     POWER LAW SEGMENTS OF THE HYBRID DISTRIBUTION
      FNPL = C2
      FNLN = 1. - C2
      D3AVLN = DM ** 3 * EXP( 9. * ALNS ** 2 / 2. )
      CON1 = -OMP / ( DMIN ** OMP - DMAX ** OMP )
      IF( P .EQ. 4. ) GO TO 120
      FMP = 4. - P
      D3AVPL = CON1 * ( DMAX ** FMP - DMIN ** FMP ) / FMP
      GO TO 125
  120 D3AVPL = CON1 * ALOG( DMAX / DMIN )
  125 CUM = CUMNOR( SD1 - 3. * ALNS )
      IF( SD1 - 3. * ALNS .GT. 0. ) CUM = 1. - CUM
      D3AVH = C1 * D3AVLN * CUM + C2 * D3AVPL
```

```
      FMPL = C2 * D3AVPL / D3AVH
      FMLN = 1. - FMPL
  126 CONTINUE
C
C     COMPUTE THE NUMBER FRACTION AND MASS FRACTION FOR THAT PART OF THE
C     SIZE GROUP THAT LIES IN THE LOG NORMAL PORTION OF THE HYBRID
C     DISTRIBUTION
      FNGLN = 0.
      FMGLN = 0.
      IF( DLOW .GE. DMIN ) GO TO 135
      DUPPER = AMIN1( DHIGH, DMIN )
      FN1 = 0.
      FM1 =0.
      SD1 = -1.
      SD2 = ALOG( DUPPER / DM ) / ALNS
      SD3 = 3. * ALNS
      IF( DLOW .LE. 0. ) GO TO 130
      SD1 = ALOG( DLOW / DM ) / ALNS
      FN1 = CUMNOR( SD1 )
      FM1 = CUMNOR( SD1 - SD3 )
  130 FN2 = CUMNOR( SD2 )
      FM2 = CUMNOR( SD2 - SD3 )
      IF( SD1 * SD2 .LE. 0. ) GO TO 131
      FNGLN = C1 * ( FN1 - FN2 )
      IF( SD2 .LT. 0. ) FNGLN = -FNGLN
      GO TO 132
  131 FNGLN = C1 * ( 1. - FN1 - FN2 )
  132 IF( ( SD1 - SD3 ) * ( SD2 - SD3 ) .LE. 0. ) GO TO 133
      FMGLN = C1 * D3AVLN * ( FM1 - FM2 ) / D3AVH
      IF( SD2 - SD3 .LT. 0. ) FMGLN = -FMGLN
      GO TO 134
  133 FMGLN = C1 * D3AVLN * ( 1. - FM1 - FM2 ) / D3AVH
C
C     COMPUTE CROSS SECTIONS FOR THIS PORTION OF THE SIZE GROUP
  134 MSIZEH = 1
      IF( MSIZE .LE. 0 ) MSIZEH = -1
      CALL CROSS( MSIZEH, MSPHER, DLOW, DUPPER, DM, S, DUM, WL, XR, XI,
     1              SIGALN, SIGSLN, SIGELN, SIGBLN, SPNLN )
C
C     COMPUTE THE NUMBER FRACTION AND MASS FRACTION FOR THAT PART OF THE
C     SIZE GROUP THAT LIES IN THE POWER LAW PORTION OF THE HYBRID
C     DISTRIBUTION
  135 FNGPL = 0.
      FMGPL =0.
      IF( DHIGH .LE. DMIN ) GO TO 147
      DLOWER = AMAX1( DLOW, DMIN )
      FNGPL = C2 * ( DLOWER ** OMP - DHIGH ** OMP ) / ( DMIN ** OMP
     1                  - DMAX ** OMP )
      IF( P .EQ. 4. ) GO TO 140
      FMGPL = FMPL * ( DLOWER ** FMP - DHIGH ** FMP ) / ( DMIN ** FMP
     1                  - DMAX ** FMP )
      GO TO 145
  140 FMGPL = FMPL * ALOG( DHIGH / DLOWER ) / ALOG( DMAX / DMIN )
C
C     COMPUTE CROSS SECTIONS FOR THIS PORTION OF THE SIZE GROUP
  145 MSIZEH = 2
      IF( MSIZE .LE. 0 ) MSIZEH = -2
      CALL CROSS( MSIZEH, MSPHER, DLOWER, DHIGH, DMIN, DMAX, P, WL, XR,
```

```
     1              XI, SIGAPL, SIGSPL, SIGEPL, SIGBPL, SPNPL )
C
C
C      COMPUTE NUMBER AND MASS FRACTIONS FOR THE SIZE GROUP
  147 FN = FNGLN + FNGPL
      FM = FMGLN + FMGPL
C
C      COMPUTE AVERAGE CUBED DIAMETER OF GROUP
      D3AV = FM * D3AVM / FN
C
C      COMPUTE CROSS SECTIONS FOR THE WHOLE SIZE GROUP
      CON1 = FNGLN / ( FNGLN + FNGPL )
      CON2 = 1. - CON1
      SIGA = CON1 * SIGALN + CON2 * SIGAPL
      SIGS = CON1 * SIGSLN + CON2 * SIGSPL
      SIGE = CON1 * SIGELN + CON2 * SIGEPL
      SIGB = CON1 * SIGBLN + CON2 * SIGBPL
C
C      COMPUTE NORMALIZED SCATTERING PATTERN FOR POSITIVE MSIZE
      IF( MSIZE .LE. 0 ) GO TO 155
      CON1 = CON1 * SIGSLN / SIGS
      CON2 = 1. - CON1
      DO 150 I = 1, 21
      SPN( I ) = CON1 * SPNLN( I ) + CON2 * SPNPL( I )
  150 CONTINUE
C
C
C      COMPUTE NUMBER OF PARTICLES PER GRAM OF MATERIAL IN THE GROUP
  155 PNG = 6. / ( PI * RHO * D3AV )
C
C      COMPUTE MASS COEFFICIENTS
  156 CMUA = PNG * SIGA
      CMUS = PNG * SIGS
      CMUE = PNG * SIGE
      CMUB = PNG * SIGB
C
C
C      THE CALCULATION FOR THIS SIZE GROUP ARE COMPLETE
C
      RETURN
C
      END
```

```
      SUBROUTINE CROSS( MSIZE, MSPHER, DLOW, DHIGH, D1M, D2S, P, WL, XR,
     1                  XI, SIGA, SIGS, SIGE, SIGB, SPN )
C
C
C     THIS ROUTINE CALCULATES THE AVERAGE ABSORPTION, SCATTERING,
C     EXTINCTION AND BACKSCATTER CROSS SECTIONS PER PARTICLE AND THE
C     NORMALIZED SCATTERING PATTERN FOR PARTICLES WITH DIAMETERS IN THE
C     SIZE INTERVAL DLOW TO DHIGH. THESE PARTICLES ARE A SUBSET OF A
C     COLLECTION OF PARTICLES WHOSE SIZES HAVE A LOG NORMAL OR A POWER
C     LAW PROBABILITY DISTRIBUTION. THE PARTICLES CAN BE SPHERICAL OR
C     NONSPHERICAL
C
C         INPUTS
C     MSIZE   = 1 THE PARTICLES HAVE A LOG NORMAL SIZE DISTRIBUTION,
C                 COMPUTE CROSS SECTIONS AND SCATTERING PATTERN
C             = -1 THE PARTICLES HAVE A LOG NORMAL SIZE DISTRIBUTION,
C                 COMPUTE CROSS SECTIONS
C             = 2 THE PARTICLES HAVE A POWER LAW SIZE DISTRIBUTION,
C                 COMPUTE CROSS SECTIONS AND SCATTERING PATTERN
C             = -2 THE PARTICLES HAVE A POWER LAW SIZE DISTRIBUTION,
C                 COMPUTE CROSS SECTIONS
C     MSPHER  = 1 THE PARTICLES ARE SPHERICAL, USE STANDARD MIE THEORY
C             = 2 THE PARTICLES ARE NONSPHERICAL, USE MODIFIED MIE
C                 THEORY
C     DLOW    = LOWER LIMIT OF PARTICLE DIAMETER RANGE (L, WHERE L IS A
C               LENGTH UNIT SUCH AS MICRONS, CENTIMETERS, METERS, ETC. )
C     DHIGH   = UPPER LIMIT OF PARTICLE DIAMETER RANGE (L)
C     D1M     = MEAN DIAMETER PARAMETER FOR THE LOG NORMAL DISTRIBUTION
C               (L)
C             = MINIMUM DIAMETER OF POWER LAW DISTRIBUTION (L)
C     D2S     = STANDARD DEVIATION PARAMETER OF THE LOG NORMAL
C               DISTRIBUTION
C             = MAXIMUM DIAMETER OF THE POWER LAW DISTRIBUTION (L)
C     P       = POWER LAW EXPONENT OF THE POWER LAW DISTRIBUTION
C     WL      = WAVELENGTH OF THE INCIDENT RADIATION (L)
C     XR      = REAL PART OF THE COMPLEX INDEX OF REFRACTION OF THE
C               PARTICLES
C     XI      = IMAGINARY PART OF THE COMPLEX INDEX OF REFRACTION OF THE
C               PARTICLES ( THE INDEX IS M = XR - I*XI SO THAT BOTH XR
C               AND XI ARE POSITIVE )
C
C         OUTPUTS
C     SIGA    = AVERAGE ABSORPTION CROSS SECTION PER PARTICLE ( L**2 )
C     SIGS    = AVERAGE SCATTERING CROSS SECTION PER PARTICLE ( L**2 )
C     SIGE    = AVERAGE EXTINCTION CROSS SECTION PER PARTICLE ( L**2 )
C     SIGB    = AVERAGE BACKSCATTER CROSS SECTION PER PARTICLE ( L**2 )
C     SPN     = NORMALIZED SCATTERING PATTERN FOR THE PARTICLES IN THE
C               GIVEN SIZE RANGE DLOW TO DHIGH. SPN(J) = SCATTERING
C               FUNCTION AT THE SCATTERING ANGLE WHOSE COSINE IS
C               0.1*(J-11), SPN IS NORMALIZED SO THAT THE INTEGRAL OF
C               SPN OVER 4 PI STERADIANS EQUALS 4 PI ( IE, AN ISOTROPIC
C               SCATTERING PATTERN HAS SPN(J) = 1.0 FOR ALL J )
C
C         NOTES
C     THE UNITS TO BE USED FOR L( LENGTH ) ARE THE USERS CHOICE, BUT ALL
C     DISTANCE INPUTS - DLOW, DHIGH, D1M, D2S( FOR POWER LAW ), WL -
C     MUST BE IN THE SAME UNITS. THE CROSS SECTION OUTPUTS - SIGA, SIGS,
C     SIGE, SIGB - ARE THEN IN UNITS OF L**2
```

```
C     THE OUTPUTS CALCULATED BY THIS ROUTINE ARE
C     CROSS SECTIONS - ONE DIVIDED BY FN TIMES THE INTEGRAL OVER
C           PARTICLE DIAMETER FROM DLOW TO DHIGH OF PROBABILITY
C           DISTRIBUTION TIMES CROSS SECTIONAL AREA ( PI * DIAMETER / 4)
C           TIMES MIE EFFICIENCY. FN IS THE FRACTION OF THE TOTAL NUMBER
C           OF  PARTICLES THAT ARE WITHIN THE SIZE RANGE DLOW TO DHIGH
C     SPN - NORMALIZED SCATTERING PATTERN FOR THE PARTICLES WITH
C           DIAMETERS BETWEEN DLOW AND DHIGH, EVALUATED AT 21 POINTS,
C           WHERE THE COSINE OF THE SCATTERING ANGLE VARIES FROM -1 TO
C           +1 BY 0.1 INCREMENTS. EQUATION IS ONE OVER THE SCATTERING
C           CROSS SECTION TIMES THE INTEGRAL OVER PARTICLE DIAMETER FROM
C           DLOW TO DHIGH OF NORMALIZED SCATTERING PATTERN AT PARTICLE
C           DIAMETER TIMES PROBABILITY DISTRIBUTION TIMES AREA( PI *
C           DIAMETER**2 / 4 ) TIMES MIE SCATTERING EFFICIENCY
C     THE PROBABILITY DISTRIBUTIONS ARE
C     LOG NORMAL = EXP( -0.5*(LN(D/DM)/LN(S))**2 )/( SQRT(2*PI)*D*LN(S))
C                  WHERE D = PARTICLE DIAMETER ( L )
C                        DM = D1M, MEAN PARTICLE DIAMETER PARAMETER ( L)
C                        S  = D2S, STANDARD DEVIATION PARAMETER
C     POWER LAW = (P-1)*D**(-P)/(DMIN**(1-P)-DMAX**(1-P))
C                 WHERE DMIN = D1M, MINIMUM PARTICLE DIAMETER OF
C                              DISTRIBUTION
C                       DMAX = D2S, MAXIMUM PARTICLE DIAMETER OF
C                              DISTRIBUTION
C     IF FOR THE LOG NORMAL DISTRIBUTION DLOW = 0 AND DHIGH IS
C     ESSENTIALLY INFINITE( LN(DHIGH/D1M) .GT. 20*LN(D2S) ) THE WHOLE
C     RANGE OF THE DISTRIBUTION IS COVERED AND THE OUTPUTS ARE FOR ALL
C     THE PARTICLES IN THE DISTRIBUTION. SIMILARLY IF DLOW = D1M AND
C     DHIGH = D2S, THEN THE WHOLE POWER LAW DISTRIBUTION IS INCLUDED
C
C
      DIMENSION SPN(21), SP(21), SP1(21), SPL(21), SPU(21), SPI(21)
C
C     SET VALUES OF PI, 4*PI, SQRT(2*PI), AND SQRT(2)
      DATA PI / 3.14159265 /, FOURPI / 12.5663706 /, SQ2PI / 2.50662827/
     1          , SQ2 / 1.41421356 /
C
C     INITIALIZATION - ZERO OUT VARIABLES
      SIGS = 0.
      SIGE = 0.
      SIGR = 0.
      DSIGEL = 0
      DO 2 IP = 1, 21
      SPN( IP ) = 0.
    2 CONTINUE
C     SET NUMBER OF STEPS INDICATOR
      NSTEP = 0
C     SET MIE DIMENSIONLESS SIZE PARAMETER INDICATOR
      LIMITA = 0
C
C     CHECK WHICH DISTRIBUTION IS TO BE USED - LOG NORMAL OR POWER LAW
      IF( IABS( MSIZE ) .EQ. 2 ) GO TO 6
C
C
C     DISTRIBUTION IS LOG NORMAL
C     SET MEAN VALUE AND STANDARD DEVIATION PARAMETERS
      DM = D1M
```

```
      S = D2S
      ALNS = ALOG( S )
C
C     CALCULATE DIAMETER AT PEAK OF PROBABILITY DISTRIBUTION
      DPEAK = DM * EXP( -ALNS**2 )
C
C
C     CALCULATE FN, THE FRACTION OF THE TOTAL NUMBER OF PARTICLES THAT
C     ARE IN THE GIVEN SIZE RANGE  ( NUMBER OF PARTICLES WITH DIAMETERS
C     BETWEEN DLOW AND DHIGH DIVIDED BY TOTAL NUMBER OF PARTICLES IN THE
C     DISTRIBUTION )
      FN1 = 0.
      E1 = -1.
      IF( DLOW .LE. 0. ) GO TO 3
      E1 = ALOG( DLOW / DM ) / ALNS
      FN1 = CUMNOR( E1 )
    3 E2 = ALOG( DHIGH / DM ) / ALNS
      FN2 = CUMNOR( E2 )
      IF( E1 * E2 .LE. 0. ) GO TO 4
      FN = FN1 - FN2
      IF( E2 .LT. 0. ) FN = -FN
      GO TO 5
    4 FN = 1. - FN1 - FN2
C
C
C     SET CONSTANT FACTOR IN LOG NORMAL PROBABILITY EQUATION
    5 CONLN = 1. / ( SQ2PI * ALNS * FN )
C     INTEGRATION STRATEGY
C     IF DPEAK IS WITHIN INTEGRATION RANGE DLOW - DHIGH, START AT DPEAK
C     AND INTEGRATE FORWARD TO DHIGH, THEN RETURN TO DPEAK AND
C     INTEGRATE BACKWARDS TO DLOW. OTHERWISE IF DPEAK IS LESS THAN DLOW
C     START AT DLOW AND INTEGRATE FORWARDS TO DHIGH. IF DPEAK IS GREATER
C     THAN DHIGH, START AT DHIGH AND INTEGRATE BACKWARDS TO DLOW
      DSTART = -1.
      IF( DPEAK .GE. DHIGH ) GO TO 100
      DSTART = DPEAK
      IF( DPEAK .LE. DLOW ) DSTART = DLOW
      GO TO 7
C
C
C     DISTRIBUTION IS POWER LAW
C     SET MINIMUM AND MAXIMUM DIAMETERS
    6 DMIN = D1M
      DMAX = D2S
C
C     CALCULATE FN FOR POWER LAW DISTRIBUTION
      OMP = 1. - P
      FN = ( DLOW**OMP - DHIGH**OMP ) / ( DMIN**OMP - DMAX**OMP )
C
C     SET CONSTANT FACTOR IN POWER LAW PROBABILITY EQUATION
      CONPL = -OMP / ( ( DMIN**OMP - DMAX**OMP ) * FN )
C
C     INTEGRATION STRATEGY
C     START AT DLOW, INTEGRATE FORWARD TO DHIGH
      DSTART = DLOW
C
C
C     THIS IS THE FORWARD INTEGRATION SECTION
```

```
C
C     SET THE INITIAL INTEGRATION STEP SIZE AND STARTING DIAMETER
    7 D = DSTART
      DELTA = 0.2 * DSTART
C
C     THIS IS THE FORWARD INTEGRATION LOOP
C     INCREMENT NUMBER OF INTEGRATION STEPS
   10 NSTEP = NSTEP + 1
C
C     CALCULATE THE DIMENSIONLESS MIE PARAMETER FOR THE CURRENT DIAMETER
      A = AMIN1( PI * D / WL, 100. )
C
C     IN THIS VERSION WE LIMIT THE MIE SIZE PARAMETER TO BE EQUAL TO 100
C     OR LESS. THIS LIMIT IS IMPOSED TO CONSERVE COMPUTER RUNNING TIME.
C     THERE WILL BE NO LOSS OF ACCURACY ON CROSS SECTION CALCULATIONS.
C     THERE MAY BE SOME ACCURACY LOSS IN THE SCATTERING PATTERN FOR A
C     DISTRIBUTION OF EXTREMELY LARGE SIZE PARTICLES
C
C     CALCULATE MIE PARAMETERS
C     IF MIE SIZE LIMIT WAS REACHED LAST TIME, USE PREVIOUSLY COMPUTED
C     VALUES
      IF( LIMITA .EQ. 1 ) GO TO 11
      CALL MIE( MSIZE, MSPHER, A, XR, XI, QSCA, QEXT, QB, SPU )
C
C     CHECK IF MIE SIZE PARAMETER LIMIT HAS BEEN REACHED
      IF( A .EQ. 100. ) LIMITA = 1
C
C     EVALUATE INTEGRANDS AND NORMALIZED SCATTERING PATTERN( FOR
C     POSITIVE MSIZE ) AT CURRENT D VALUE
   11 AREA = PI * D**2 / 4.
      IF( IABS( MSIZE ) .EQ. 2 ) GO TO 12
      PROB = CONLN * EXP( -0.5 * ( ALOG( D / DM ) / ALNS )**2 ) / D
      GO TO 13
   12 PROB = CONPL / D**P
   13 CNST = PROB * AREA
      XINTS = CNST * QSCA
      XINTE = CNST * QEXT
      XINTB = CNST * QB
      IF( MSIZE .LE. 0 ) GO TO 15
      CONS = 4. / ( A**2 * QSCA )
      DO 14 IP = 1, 21
      SP( IP ) = CONS * SPU ( IP )
   14 CONTINUE
C
C     CHECK IF THIS IS THE FIRST EVALUATION POINT
   15 IF( NSTEP .GT. 1 ) GO TO 17
C
C     SAVE INTEGRAND VALUES FROM DSTART FOR BACKWARDS INTEGRATION
      XINTS1 = XINTS
      XINTE1 = XINTE
      XINTB1 = XINTB
      IF( MSIZE .LE. 0 ) GO TO 55
      DO 16 IP = 1, 21
      SP1( IP ) = SP( IP )
   16 CONTINUE
      GO TO 55
C
C     USE POWER LAW INTEGRATION BETWEEN THIS POINT AND PREVIOUS POINT
```

```
C     COMPUTE EXPONENT OF POWER LAW
   17 ALDDL = ALOG( D / DL )
      EXS = ALOG( XINTS / XINTSL ) / ALDDL
      EXE = ALOG( XINTE / XINTEL ) / ALDDL
      EXB = ALOG( XINTB / XINTBL ) / ALDDL
C
      IF( ABS( EXS + 1. ) .LE. 1.E-3 ) GO TO 18
      DSIGS = XINTSL * DL* ( ( D / DL )**( EXS + 1. ) -1. ) / ( EXS + 1.
     1)
      GO TO 20
   18 DSIGS = XINTSL * DL * ALDDL
   20 IF( ABS( EXE + 1. ) .LE. 1.E-3 ) GO TO 25
      DSIGE = XINTEL * DL* ( ( D / DL )**( EXE + 1. ) -1. ) / ( EXE + 1.
     1)
      GO TO 30
   25 DSIGE = XINTEL * DL * ALDDL
   30 IF( ABS( EXB + 1. ) .LE. 1.E-3 ) GO TO 35
      DSIGB = XINTBL * DL* ( ( D / DL )**( EXB + 1. ) -1. ) / ( EXB + 1.
     1)
      GO TO 40
   35 DSIGB = XINTBL * DL * ALDDL
C
C     ADD CONTRIBUTION FROM THIS INCREMENT TO TOTAL
   40 SIGS = SIGS + DSIGS
      SIGE = SIGE + DSIGE
      SIGB = SIGB + DSIGB
      IF( NSIZE .LE. 0. ) GO TO 45
      CON2 = DSIGS / SIGS
      CON1 = 1. - CON2
      DO 43 IP = 1, 21
      EXSP = ALOG( XINTS * SP( IP ) / ( XINTSL * SPL( IP ) ) ) / ALDDL
      IF( ABS( EXSP + 1. ) .LE. 1.E-3 ) GO TO 41
      SPI( IP ) = XINTSL * SPL( IP ) * DL * ( ( D / DL ) ** ( EXSP +  1.
     1           ) - 1. ) / ( ( EXSP + 1. ) * DSIGS )
      GO TO 42
   41 SPI( IP ) = XINTSL * SPL( IP ) * DL * ALDDL / DSIGS
   42 SPN( IP ) = CON1 * SPN( IP ) + CON2 * SPI( IP )
   43 CONTINUE
C
C     CHECK IF THE INTEGRAL PARTIAL SUMS HAVE ALREADY CONVERGED TO FINAL
C     VALUES ( IE, IF ALL SENSIBLE CONTRIBUTIONS TO THE INTEGRALS HAVE
C     ALREADY BEEN INCLUDED ) CRITERION IS THAT THE LAST CONTRIBUTION TO
C     THE EXTINCTION CROSS SECTION IS LESS THAN 10**-4 OF THE TOTAL
C     COMPUTED THUS FAR
   45 IF( DSIGE / SIGE .LT. 1.E-4 ) GO TO 100
C
C     CONVERGENCE HAS NOT YET BEEN REACHED, DO NEXT INCREMENT
C     SAVE INTEGRAND VALUES AND DIAMETER FROM THIS STEP
   55 XINTSL = XINTS
      XINTEL = XINTE
      XINTBL = XINTB
      DL = D
      IF( NSIZE .LE. 0 ) GO TO 61
      DO 60 IP = 1, 21
      SPL( IP ) = SP( IP )
   60 CONTINUE
   61 IF( NSTEP .LE. 1 ) GO TO 65
C
```

```
C      COMPUTE STEP SIZE FOR NEXT INCREMENT
       DELTA = D * AMAX1( 0.2, EXP( 1. / AMAX1( ABS( EXE ), 1. ) ) - 1. )
       RATIO = DSIGEL / DSIGE
       IF( RATIO .GT. 1. ) DELTA = DELTA * RATIO
C
C      SAVE DSIGE VALUE
       DSIGEL = DSIGE
C
C      CHECK IF FORWARD INTEGRATION LIMIT HAS BEEN REACHED
       IF( D .GE. DHIGH ) GO TO 100
C
C      LIMIT HAS NOT YET BEEN REACHED, INCREMENT D FOR NEXT STEP
    65 D = D + DELTA
       IF( D .GT. DHIGH ) D = DHIGH
C      DO NEXT STEP
       GO TO 10
C
C
C      THIS IS THE BACKWARDS INTEGRATION SECTION FOR THE LOG NORMAL
C      DISTRIBUTION .
C
C      CHECK IF THE FORWARD INTEGRATION INCLUDED WHOLE INTEGRATION RANGE
   100 IF( DSTART .EQ. DLOW ) GO TO 200
C
C      RESET INTEGRATION STEP COUNTER AND DSIGEL VALUE
       NSTEP = 0
       DSIGEL = 0.
C
C      IF FORWARD INTEGRATION BEGAN AT PROBABILITY PEAK, USE SAVED VALUES
C      FOR STARTING POINT, OTHERWISE CALCULATE STARTING VALUES
       IF( DSTART .EQ. DPEAK ) GO TO 105
       DSTART = DHIGH
       D = DSTART
       DELTA = -0.2 * DSTART
       GO TO 115
   105 XINTSL = XINTS1
       XINTEL = XINTE1
       XINTBL = XINTB1
       D = DSTART
       DL = DSTART
       DELTA = -0.2 * DSTART
       NSTEP = 1
       IF( MSIZE .LE. 0 ) GO TO 165
       DO 110 IP = 1, 21
       SPL( IP ) = SP1( IP )
   110 CONTINUE
       GO TO 165
C
C
C
C      THIS IS THE BACKWARDS INTEGRATION LOOP
C
   115 NSTEP = NSTEP + 1
C
C      CALCULATE THE DIMENSIONLESS MIE PARAMETER FOR THE CURRENT DIAMETER
       A = AMIN1( PI * D / WL, 100. )
C
C      CALCULATE MIE PARAMETERS
```

```
C      IF MIE SIZE LIMIT HAS REACHED LAST TIME, USE PREVIOUSLY COMPUTED
C      VALUES
       IF( LIMITA .EQ. 1 .AND. A .GE. 100. ) GO TO 117
C
       CALL MIE( MSIZE, MSPHER, A, XR, XI, QSCA, QEXT, QB, SPU )
C
C      CHECK IF MIE SIZE PARAMETER LIMIT HAS BEEN REACHED
       IF( A .EQ. 100. ) LIMITA = 1
C
C      EVALUATE INTEGRANDS AND NORMALIZED SCATTERING PATTERN( FOR
C      POSITIVE MSIZE ) AT CURRENT D VALUE
  117 AREA = PI * D**2 / 4.
      PROB = CONLN * EXP( -0.5 * ( ALOG( D / DM ) / ALNS )**2 ) / D
      CNST = PROB * AREA
      XINTS = CNST * QSCA
      XINTE = CNST * QEXT
      XINTB = CNST * QB
      IF( MSIZE .LE. 0 ) GO TO 119
      CONS = 4. / ( A**2 * QSCA )
      DO 118 IP = 1, 21
      SP( IP ) = CONS * SPU ( IP )
  118 CONTINUE
C
C      CHECK IF THIS IS THE FIRST EVALUATION POINT
  119 IF( NSTEP .LE. 1 ) GO TO 155
C
C      USE POWER LAW INTEGRATION BETWEEN THIS POINT AND PREVIOUS POINT
C      COMPUTE EXPONENT OF POWER LAW
      ALDDL = ALOG( DL / D )
      EXS = ALOG( XINTSL / XINTS ) / ALDDL
      EXE = ALOG( XINTEL / XINTE ) / ALDDL
      EXB = ALOG( XINTBL / XINTB ) / ALDDL
C
      IF( ABS( EXS + 1. ) .LE. 1.E-3 ) GO TO 120
      DSIGS = XINTS * D * ( ( DL / D )**( EXS + 1. ) - 1. ) / ( EXS + 1.
     1)
      GO TO 125
  120 DSIGS = XINTS * D * ALDDL
  125 IF( ABS( EXE + 1. ) .LE. 1.E-3 ) GO TO 130
      DSIGE = XINTE * D * ( ( DL / D )**( EXE + 1. ) - 1. ) / ( EXE + 1.
     1)
      GO TO 135
  130 DSIGE = XINTE * D * ALDDL
  135 IF( ABS ( EXB + 1. ) .LE. 1.E-3 ) GO TO 140
      DSIGB = XINTB * D * ( ( DL / D )**( EXB + 1. ) - 1. ) / ( EXB + 1.
     1)
      GO TO 145
  140 DSIGB = XINTB * D * ALDDL
C
C      ADD CONTRIBUTION FROM THIS INCREMENT TO TOTAL
  145 SIGS = SIGS + DSIGS
      SIGE = SIGE + DSIGE
      SIGB = SIGB + DSIGB
      IF( MSIZE .LE. 0. ) GO TO 150
      CON2 = DSIGS / SIGS
      CON1 = 1. - CON2
      DO 148 IP = 1,21
      EXSP = ALOG( XINTSL * SPL( IP ) / ( XINTS * SP( IP ) ) ) / ALDDL
```

```
      IF( ABS( EXSP + 1. ) .LE. 1.E-3 ) GO TO 146
      SPI( IP ) = XINTS * SP( IP ) * D * ( ( DL / D ) ** ( EXSP + 1. )
     1             - 1. ) / ( ( EXSP + 1. ) * DSIGS )
      GO TO 147
  146 SPI( IP ) = XINTS * SP( IP ) * D * ALODL / DSIGS
  147 SPN( IP ) = CON1 * SPN( IP ) + CON2 * SPI( IP )
  148 CONTINUE
C
C     CHECK IF CONVERGENCE HAS BEEN REACHED.  CRITERION IS THAT THE LAST
C     CONTRIBUTION TO THE EXTINCTION CROSS SECTION IS LESS THAN 10**-4
C     OF THE TOTAL
  150 IF( DSIGE / SIGE .LT. 1.E-4 ) GO TO 200
C
C     CONVERGENCE HAS NOT YET BEEN REACHED, DO NEXT INCREMENT
C     SAVE INTEGRAND VALUES AND DIAMETER FROM THIS STEP
  155 XINTSL = XINTS
      XINTEL = XINTE
      XINTBL = XINTB
      DL = D
      IF( NSIZE .LE. 0 ) GO TO 161
      DO 160 IP = 1, 21
      SPL( IP ) = SP( IP )
  160 CONTINUE
  161 IF( NSTEP .LE. 1 ) GO TO 165
C
C     COMPUTE STEP SIZE FOR NEXT INCREMENT
      DELTA = -D * AMAX1( 0.2, 1. - EXP( -1. / AMAX1( ABS( EXE ), 1. ) )
     1)
      RATIO = DSIGEL / DSIGE
      IF( RATIO .GT. 1. ) DELTA = AMAX1( -0.9 * D, DELTA * RATIO )
C
C     SAVE DSIGE VALUE
      DSIGEL = DSIGE
C
C     CHECK IF BACKWARD INTEGRATION LIMIT HAS BEEN REACHED
      IF( D .LE. DLOW ) GO TO 200
C
C     LIMIT HAS NOT YET BEEN REACHED, INCREMENT D FOR NEXT STEP
  165 D = D + DELTA
      IF( D .LT. DLOW ) D = DLOW
C     DO NEXT STEP
      GO TO 115
C
C
C     INTEGRATION COMPLETE, SET VALUE OF SIGA
  200 SIGA = SIGE -SIGS
C
      RETURN
      END
```

```
      SUBROUTINE MIE( MSIZE, MSPHER, X, DR, DI, QSCA, QEXT, QBS, S )
C
C     THIS ROUTINE USES MIE  THEORY TO CALCULATE THE EFFICIENCIES FOR
C     SCATTERING AND ABSORPTION AND THE SCATTERING PATTERN FOR A SINGLE
C     UNIFORM SPHERICAL PARTICLE
C
C     THE METHOD FOR MODIFYING THE MIE CALCULATION FOR NONSPHERICAL
C     PARTICLES IS THAT OF CHYLEK, GRAMS, AND PINNICK
C              LIGHT SCATTERING BY IRREGULAR RANDOMLY ORIENTED PARTICLES
C              SCIENCE, VOL 193, 6 AUGUST 1976, PP 480-482
C     THE METHOD IS BASED ON THE ASSUMPTION THAT SURFACE WAVES ARE
C     PRESENT IN SCATTERING BY SPHERICAL PARTICLES, BUT THEY ARE ABSENT
C     IN SCATTERING BY IRREGULAR PARTICLES
C
C         INPUTS
C     MSIZE  = POSITIVE INTEGER, COMPUTE BOTH CROSS SECTIONS AND
C              SCATTERING PATTERN
C            = NEGATIVE INTEGER, COMPUTE CROSS SECTIONS ONLY
C     MSPHER  = 1 THE PARTICLES ARE SPHERICAL, USE STANDARD MIE THEORY
C             = 2 THE PARTICLES ARE NONSPHERICAL, USE MODIFIED MIE
C                 THEORY
C     X       = NORMALIZED SIZE PARAMETER, WHICH EQUALS TWO PI TIMES
C               THE RADIUS OF THE SPHERE DIVIDED BY THE WAVELENGTH OF THE
C               INCIDENT RADIATION
C     DR      = REAL PART OF THE COMPLEX INDEX OF REFRACTION OF THE
C               SPHERE
C     DI      = IMAGINARY PART OF THE COMPLEX INDEX OF REFRACTION OF THE
C               SPHERE ( NOTE THAT THE COMPLEX INDEX OF REFRACTION IS
C               ASSUMED TO BE M = DR - I*DI SO THAT BOTH DR AND DI ARE
C               POSITIVE )
C
C         OUTPUTS
C     QSCA    = SCATTERING EFFICIENCY, WHICH EQUALS THE SCATTERING CROSS
C               SECTION OF THE SPHERE DIVIDED BY THE CROSS SECTIONAL AREA
C               OF THE SPHERE ( SIGMA/(PI*RADIUS**2)
C     QEXT    = EXTINCTION EFFICIENCY, WHICH EQUALS THE TOTAL
C               ( SCATTERING + ABSORPTION ) CROSS SECTION OF THE SPHERE
C               DIVIDED BY THE CROSS SECTIONAL AREA OF THE SPHERE
C     QBS     = BACKSCATTER EFFICIENCY, WHICH EQUALS THE SCATTERING CROSS
C               SECTION( IN THE BACKWARDS DIRECTION) DIVIDED BY THE CROSS
C               SECTIONAL AREA OF THE SPHERE( SIGMA/(PI*RADIUS**2)
C     S       = SCATTERING PATTERN OF THE RADIATION SCATTERED BY THE
C               SPHERE, ASSUMING INCIDENT UNPOLARIZED RADIATION, S(J) =
C               SCATTERING FUNCTION FOR THE SCATTERING ANGLE WHOSE COSINE
C               IS 0.1*(J-11), S IS UN-NORMALIZED, THAT IS, THE INTEGRAL
C               OF S OVER 4 PI STERADIANS EQUALS PI*QSCA*X**2
C
C
      DIMENSION S(21), XMU(21), S1(21), S2(21), PP1(21), PP2(21),
     1      PT1(21), PT2(21), PT(21), PP(21)
      DIMENSION ANR(200)
      COMPLEX D,Z,EM1,EM2,EN,ANF,ANR,ANZ,AN,BN,QBSC
      COMPLEX S1, S2
C
C     SET THE VALUES OF THE COSINE OF THE SCATTERING ANGLE AT WHICH THE
C     SCATTERING PATTERN IS TO BE EVALUATED
      DATA XMU / -1., -.9, -.8, -.7, -.6, -.5, -.4, -.3, -.2, -.1, 0.,
     1     .1, .2, .3, .4, .5, .6, .7, .8, .9, 1. /
```

```
C
C
C      SET VALUES OF COMPLEX INDEX OF REFRACTION AND MIE VARIABLE
       D = CMPLX( DR, -DI )
       Z = X * D
C
C      SET INITIAL VALUES OF RICCATI-BESSEL FUNCTION
       EM1 = CMPLX( SIN( X ), COS( X ) )
       EM2 = CMPLX( COS( X ), -SIN( X ) )
C
C      ZERO OUT EFFICIENCY VARIABLES AND SCATTERING PATTERN VARIABLES
       IF( MSIZE .LE. 0 ) GO TO 20
       DO 10 I = 1, 21
       S1( I ) = ( 0., 0. )
       S2( I ) = ( 0., 0. )
       PP1(I) = 0.
       PT1(I) = 0.
       PP2(I) = 0.
       PT2(I) = 0.
    10 CONTINUE
    20 QSCA = 0.
       QEXT = 0.
       QBSC = ( 0., 0. )
C
C      SET UP ARRAY OF ANF VALUES - USE LENTZ BACKWARDS RECURSION
C      TECHNIQUE ( SEE COMPLEX FUNCTION ANF )
       NX = 1.5 * X
       NX = MAX0( 2, MIN0( NX, 200 ) )
       ANR(NX) = ANF( NX, Z )
       NXM1 = NX - 1
       DO 30 I = 1, NXM1
       N = NX + 1 - I
       CN = FLOAT( N )
       ANR(N-1) = CN / Z - (1.,0.) / ( CN / Z + ANR(N) )
    30 CONTINUE
C
C
C      CALCULATE THE EFFICIENCIES AND SCATTERING PATTERN USING THE MIE
C      INFINITE SERIES EXPANSION FORMULAS
       X2 = X ** 2
       ONE = -1.
       DO 100 N = 1, 200
       FN = N
       ONE = -ONE
       C1 = 2. * FN - 1.
       EN = C1 * EM1 / X - EM2
       IF ( N .LE. NX ) ANZ = ANR(N)
       IF ( N .GT. NX ) ANZ = ANF( N, Z )
       CFNOX = FN / X
       C1 = REAL( EN )
       C2 = REAL( EM1 )
       AN = ( ( ANZ / D + CFNOX ) * C1 - C2 ) /
      1     ( ( ANZ / D + CFNOX ) * EN - EM1 )
       BN = ( ( D * ANZ + CFNOX ) * C1 - C2 ) /
      1     ( ( D * ANZ + CFNOX ) * EN - EM1 )
C
C      CHECK IF PARTICLES ARE SPHERICAL OR NONSPHERICAL
```

```
      IF( NSPHER .LE. 1 ) GO TO 35
C
C     THE PARTICLES ARE NONSPHERICAL, MODIFY THE VALUES OF AN AND BN IF
C     THEY ARE NEAR A RESONANCE PEAK ( DUE TO SURFACE WAVES )
C     MAKE MODIFICATION ONLY FOR MIE ORDERS OF THREE AND ABOVE
      IF( N .LT. 3 ) GO TO 35
C
C     CHECK IF DIMENSIONLESS SIZE PARAMETER IS BEYOND THE RESONANCE
C     REGION
      IF( X .GT. 1.1 * FN ) GO TO 35
C
C     WE ARE NOT BEYOND THE RESONANCE, LIMIT AN AND BN
      IF( REAL( AN ) .GT. 0.5 ) AN = ( 0.5, 0. )
      IF( REAL( BN ) .GT. 0.5 ) BN = ( 0.5, 0. )
C
   35 XFACT = 2. * FN + 1.
      XFACB = ONE * ( FN + 0.5 )
      QSCA = QSCA + XFACT * ( CABS( AN ) **2 + CABS( BN ) **2 )
      QEXT = QEXT + XFACT * REAL( AN + BN )
      QBSC = QBSC + XFACB * ( AN - BN )
      EM2 = EM1
      EM1 = EN
      IF( MSIZE .LE. 0 ) GO TO 80
      DO 70 I = 1, 21
      IF ( N .GT. 2 ) GO TO 50
      IF ( N .EQ. 2 ) GO TO 40
      PP(I) = 1.
      PT(I) = XMU(I)
      GO TO 60
   40 PP(I) = 3. * XMU(I)
      PT(I) = 6. * XMU(I) **2 - 3.
      GO TO 60
   50 PP(I) = ( ( 2. * FN - 1. ) * XMU(I) * PP1(I) - FN * PP2(I) ) /
     1     ( FN - 1. )
      PT(I) = XMU(I) * ( PP(I) - PP2(I) ) - ( 2. * FN - 1. ) *
     1     ( 1. - XMU(I) **2 ) * PP1(I) + PT2(I)
   60 CXFACT = ( 2. * FN + 1. ) / ( FN **2 + FN )
      C1 = PP(I)
      C2 = PT(I)
      S1(I) = S1(I) + CXFACT * ( AN * C1 + BN * C2 )
      S2(I) = S2(I) + CXFACT * ( BN * C1 + AN * C2 )
      PP2(I) = PP1(I)
      PT2(I) = PT1(I)
      PP1(I) = PP(I)
      PT1(I) = PT(I)
   70 CONTINUE
   80 IF( FN .LT. 1.2 * X .OR. N .EQ. 1 ) GO TO 90
C
C     CHECK IF THE INFINITE SERIES HAS CONVERGED
      IF ( ABS( 1. - AMAX1( QEXT, QEXTST ) / AMIN1( QEXT, QEXTST ) )
     1     .LE. 1.E-3 ) GO TO 110
C
C     CONVERGENCE HAS NOT BEEN REACHED, COMPUTE NEXT TERM IN SERIES
   90 QEXTST = QEXT
  100 CONTINUE
C
C     SERIES HAS CONVERGED, SET THE CROSS SECTION VALUES
  110 QEXT = 2. * QEXT / X2
```

```
      QSCA = 2. * QSCA / X2
      QBS = 4. * ( CABS( QBSC ) ** 2 ) / X2
C
C     FOR POSITIVE MSIZE, SET THE VALUES OF THE UNPOLARIZED SCATTERING
C     PATTERN
      IF( MSIZE .LE. 0 ) RETURN
      DO 120 I = 1, 21
      S(I) = 0.5 * ( CABS( S1(I) ) **2 + CABS( S2(I) ) **2 )
  120 CONTINUE
C
      RETURN
      END
```

```
      COMPLEX FUNCTION ANF( INDEX, Z )
C
C     THIS ROUTINE IS CALLED BY MIE
C     THIS IS A WOF ROUTINE - DOCUMENTED IN REPORT GE77TMP-22
C
C     THIS FUNCTION EVALUATES THE  COMPLEX QUANTITY A(N,Z) WHICH IS USED
C     IN THE MIE FORMULAS, WHERE
C     A(N,Z) = -N/Z + J(N-1/2,Z)/J(N+1/2,Z)
C     Z      = M*ALPHA
C     M      = M(REAL)-I*M(IMAGINARY) = COMPLEX INDEX OF REFRACTION
C     ALPHA  = 2*PI*R/WAVELENGTH = NORMALIZED SIZE PARAMETER
C     R      = RADIUS OF SPHERE
C     N      = ORDER OF THE FUNCTION
C     J      = BESSEL FUNCTION OF COMPLEX ARGUMENT AND HALF-INTEGER
C              ORDER
C
C     THE METHOD OF EVALUATION USES THE CONTINUED FRACTION ALGORITHM OF
C     WILLIAM J LENTZ - GENERATING BESSEL FUNCTIONS IN MIE SCATTERING
C                       CALCULATIONS USING CONTINUED FRACTIONS
C                       APPLIED OPTICS, VOL. 15, NO. 3, MARCH 1976
C
C
C         INPUTS
C     INDEX = ORDER OF A(N,Z), THAT IS, INDEX = N
C     Z     = COMPLEX ARGUMENT
C
C         OUTPUT
C     ANF   = A(N,Z)
C
C
      COMPLEX Z, N, D, T, PN, PD, T1, T2 , E
C
C     DEFINE ARITHMETIC STATEMENT
      C( X ) = 2. * S * ( FN - 0.5 + XI )
C
C     SET VALUE OF FIRST PARTIAL FRACTION TERM FOR NUMERATOR (PN)
      FN = INDEX
      S = -1.
      CP = 2. * FN + 1.
      PN=CP/Z
C
C     SET VALUE OF FIRST PARTIAL CONVERGENT FOR NUMERATOR (N)
      N=PN
C
C     CALCULATE SECOND PARTIAL FRACTION AND CONVERGENT FOR NUMERATOR
      CP = -2. * FN - 3.
      T=CP/Z
      PN=T+(1.,0.)/PN
      N=N*PN
C
C     SET VALUE OF FIRST PARTIAL FRACTION (PD) AND CONVERGENT (D) FOR
C     DENOM    OR
      PD=T
      D=PD
C
C
C     CALCULATE THE HIGHER ORDERS OF THE PARTIAL FRACTIONS AND
C     CONVERGENTS
```

```
          XI=2.
          DO 30 J = 1 , 100
          XI=XI+1.
          S = -S
          T = C( X ) / Z
          PN=T+(1.,0.)/PN
          PD=T+(1.,0.)/PD
C
C
C         IN THE RARE INSTANCE THAT THE NUMERATOR PARTIAL FRACTION TERM IS
C         NEAR ZERO, USE THE LENTZ ALGORITHM IMPROVEMENT METHOD TO INSURE
C         ACCURACY
          IF ( CABS( PN ) .GT. 1.E-4 ) GO TO 20
          S = -S
          XI = XI + 1.
          T1 = C( X ) / Z
          E = T1 * PN + (1.,0.)
          N = N * E
          S = -S
          XI = XI + 1.
          T2 = C( X ) / Z
          PN = T2 + PN / E
C
C         IF THE DENOMINATOR PARTIAL FRACTION TERM IS NEAR ZERO, USE THE
C         ALGORITHM IMPROVCMENT METHOD
          IF ( CABS( PD ) .GT. 1.E-4 ) GO TO 10
          E = T1 * PD + (1.,0.)
          D = D * E
          PD = T2 + PD / E
          GO TO 20
C
       10 D = D * PD
          PD=T1+(1.,0.)/PD
          D = D * PD
          PD=T2+(1.,0.)/PD
C
C
       20 N = N * PN
          D = D * PD
C
C         CHECK IF CONVERGENCE HAS BEEN REACHED
          IF ( ABS( CABS( PN ) / CABS( PD ) - 1. ) .LE. 1.E-6 ) GO TO 40
       30 CONTINUE
C
C
C         CONVERGENCE HAS BEEN REACHED, SET VALUE OF ANF
       40 ANF = -FN / Z + N / D
C
          RETURN
          END
```

```
      FUNCTION CUMNOR( X )
C
C     CUMNOR IS THE CUMULATIVE DISTRIBUTION OF THE NORMAL RANDOM
C     PROBABILITY DISTRIBUTION FOR NEGATIVE X AND IS ONE MINUS THE
C     CUMULATIVE DISTRIBUTION FOR POSITIVE X
C
C     THE CUMULATIVE DISTRIBUTION OF THE NORMAL RANDOM VARIABLE IS
C     1/SQRT(2*PI) TIMES THE INTEGRAL FROM MINUS INFINITY TO X OF
C     EXP(-T**2 / 2 )  DT
C
C     FOR ABS(X) LESS THAN 5, WE USE THE POLYNOMIAL APPROXIMATION
C     FORMULA 26.2.17 IN THE HANDBOOK OF MATHEMATICAL FUNCTIONS BY
C     ABRAMOWITZ AND STEGUN, MARCH 1965. FOR ABS(X) GREATER OR EQUAL TO
C     5, WE USE THE ASYMPTOTIC APPROXIMATION FORMULA 26.2.24
C
C     SET POLYNOMIAL CONSTANTS
      DATA B1/ .31938153/, B2/ -.356563782/, B3/ 1.781477937/,
     1     B4/ -1.821255978/, B5/ 1.330274429/, P/ .2316419/
C
C     SET VALUE OF SQRT( 2*PI )
      DATA SQ2PI/ 2.50662827/
C
C
      AX = ABS( X )
      IF( AX .GE. 5. ) GO TO 10
C
C
C     ABS(X) IS LESS THAN 5, USE POLYNOMIAL APPROXIMATION
      T = 1. / ( 1. + P * AX )
      APPROX = EXP( -AX ** 2 / 2. ) * T * ( B1 + T * ( B2 + T * ( B3 + T
     1                               * ( B4 + T * B5 ) ) ) ) / SQ2PI
      GO TO 20
C
C
C     ABS(X) IS GREATER THAN OR EQUAL TO 5, USE ASYMPTOTIC APPROXIMATION
   10 APPROX = 0.
      IF( AX .LT. 13. ) APPROX = ( SQRT( 4. + AX **2 ) - AX ) *
     1                           EXP( - AX ** 2 / 2. ) / ( 2. * SQ2PI )
C
C
C     SET VALUE OF CUMNOR
   20 CUMNOR = APPROX
C
      RETURN
C
      END
```

```
      SUBROUTINE INITCG
C
C     THIS ROUTINE CALCULATES THE INITIAL PROPERTIES OF THE DUST CLOUDS
C     FOR EACH BURST
C
C     INPUTS FROM CINPT COMMON AREAS
C     W(IW)       = EQUIVALENT TNT YIELD OF BURST IW (LBS TNT)
C     FH(IW)      = FRACTION OF YIELD APPEARING AS HYDRODYNAMIC ENERGY
C                     FOR BURST IW
C     CT(IW)      = INITIAL MAIN CLOUD SHAPE FACTOR FOR THE DIRECTION
C                     ALONG THE SHELL TRACK FOR BURST IW
C     CP(IW)      = INITIAL MAIN CLOUD SHAPE FACTOR FOR THE DIRECTION
C                     PERPENDICULAR TO THE SHELL TRACK FOR BURST IW
C     CV(IW)      = INITIAL MAIN CLOUD SHAPE FACTOR FOR THE VERTICAL
C                     DIRECTION
C     FCM(IW)     = FRACTION OF THE APPARENT CRATER MASS OF BURST IW THAT
C                     IS LOFTED INTO THE AIR
C     ACV(IW)     = APPARENT CRATER VOLUME SCALING FACTOR FOR BURST IW
C                     (CUBIC METERS PER (LB TNT)**1.111 )
C     PHIBDG(IW) = AZIMUTH OF SHELL TRACK OF BURST IW (DEGREES,
C                     MEASURED CLOCKWISE FROM THE Y AXIS)
C     RHOD        = BULK DENSITY OF THE LOFTED DUST GRAINS (GM/CM3)
C     RHOC        = BULK DENSITY OF THE CARBON PARTICLES (GM/CM3)
C     FH2O        = SOIL MOISTURE FRACTION (MASS OF WATER IN SOIL DIVIDED
C                     BY TOTAL MASS OF SOIL INCLUDING WATER)
C     XLC         = CARBON YIELD FRACTON (LB OF CARBON PRODUCED PER LB
C                     OF TNT)
C     RMAB        = RATIO OF THE MASS OF MODE A DUST PARTICLES TO THE
C                     MASS OF MODE B DUST PARTICLES IN THE LOFTED CLOUD
C     RBASE       = RATIO OF THE MASS IN THE BASE CLOUD TO THE MASS IN
C                     THE MAIN CLOUD
C     ALPHA       = AIR ENTRAINMENT FACTOR FOR RISING CLOUD MODEL
C     CDRAG       = DRAG COEFFICIENT FOR RISING CLOUD MODEL
C     RHOA        = AMBIENT AIR DENSITY AT GROUND LEVEL (GM/CM3)
C     VWIND       = MEAN WIND VELOCITY AT REFERENCE ALTITUDE (METERS/S)
C     ALTW        = WIND REFERENCE ALTITUDE (METERS)
C     PVW         = POWER LAW EXPONENT OF VERTICAL PROFILE OF MEAN WIND
C                     VELOCITY
C     PHIWDG      = AZIMUTH OF MEAN WIND VELOCITY (MEASURED CLOCKWISE
C                     FROM THE Y AXIS) ( DEGREES)
C
C     OUTPUTS TO CINITG COMMON
C     RI(IW)   = INITIAL RADIUS OF THE EQUIVALENT SPHERICAL CLOUD FOR
C                  BURST NUMBER IW (METERS)
C     RTI(IW) = DUST CLOUD INITIAL RADIUS IN THE SHELL TRACK DIRECTION
C                  (METERS)
C     RPI(IW) = DUST CLOUD INITIAL RADIUS IN THE SHELL CROSS TRACK
C                  DIRECTION (METERS)
C     RVI(IW) = DUST CLOUD INITIAL RADIUS IN THE VERTICAL DIRECTION
C                  (METERS)
C     XKS(IW) = IDEAL SPHERICAL CLOUD HORIZONTAL DIFFUSION CONSTANT
C                  (METERS2/S)
C     FR(IW)   = IDEAL SPHERICAL CLOUD RISE CONSTANT
C     XKV(IW) = DUST CLOUD VERTICAL DIFFUSION CONSTANT (METERS2/S)
C     RTO(IW) = INITIAL RADIUS OF DUST CLOUD IN WIND TRACK DIRECTION
C                  (METERS)
C     RPO(IW) = INITIAL RADIUS OF DUST CLOUD IN WIND CTOSS TRACK
C                  DIRECTION (METERS)
```

```
C      FMAC    = FRACTION OF MAIN CLOUD DUST MASS IN MODE A PARTICLES
C      FMBC    = FRACTION OF MAIN CLOUD DUST MASS IN MODE B PARTICLES
C      SINPW   = SINE OF THE WIND AZIMUTH ANGLE
C      COSPW   = COSINE OF THE WIND AZIMUTH ANGLE
C      VW10    = WIND VELOCITY AT 10 METERS ALTITUDE (METERS/S)
C      VW10X   = X COMPONENT OF THE WIND VELOCITY AT 10 METERS ALTITUDE
C                (METERS/S)
C      VW10Y   = Y COMPONENT OF THE WIND VELOCITY AT 10 METERS ALTITUDE
C                (METERS/S)
C      VWRVI(IW)  = WIND VELOCITY AT THE ALTITUDE OF THE INITIAL VERTICAL
C                   RADIUS OF BURST IW (METERS/S)
C      VWRVIX(IW) = X COMPONENT OF THE WIND VELOCITY AT THE ALTITUDE OF
C                   THE INITIAL VERTICAL RADIUS OF BURST IW ( METERS/S)
C      VWRVIY(IW) = Y COMPONENT OF THE WIND VELOCITY AT THE ALTITUDE OF
C                   THE INITIAL VERTICAL RADIUS OF BURST IW ( METERS/S)
C      TDMAIN(IW) = TIME DELAY BEFORE HORIZONTAL MOTION DUE TO WIND FOR
C                   THE MAIN DUST CLOUD OF BURST IW (SECONDS)
C      TDBASE(IW) = TIME DELAY BEFORE HORIZONTAL MOTION DUE TO WIND FOR
C                   THE BASE DUST CLOUD OF BURST IW (SECONDS)
C      TMASSD(IW) = TOTAL INITIAL DUST MASS LOFTED IN MAIN CLOUD OF BURST
C                   IW (GM)
C      TMASSC(IW) = TOTAL INITIAL CARBON MASS LOFTED IN MAIN CLOUD OF
C                   BURST IW (GM)
C
       COMMON / CINPT1 / W(10), FH(10), CT(10), CP(10), CV(10), XB(10),
      1                  YB(10), ZB(10), DOB(10), FCM(10), ACV(10),
      2                  PHIBDG(10)
       COMMON / CINPT4 / RHOG, RHOD, RHOC, FH2O, XLC, RMAB, RBASE
       COMMON / CINPT5 / PSF, ALPHA, CDRAG, RHOA, ELEVG, TAIR, TLAPSE,
      1                  ALTIV, VWIND, ALTW, PVW, PHIWDG
       COMMON / CINPT6 / NW, NDG, NRT, NTIME, NPROB, IPRINT
       COMMON / CINITG / RI(10), RTI(10), RPI(10), RVI(10), XKS(10),
      1                  FR(10), XKV(10), RTO(10), RPO(10), SINPW, COSPW,
      2                  VW10, VW10X, VW10Y, VWRVI(10), VWRVIX(10),
      3                  VWRVIY(10), TMASSD(10), TMASSC(10), FMAC, FMBC,
      4                  POWER, TDMAIN(10), TDBASE(10)
       COMMON / TAPE / ITAPE, JTAPE
C
       DATA THIRD / 0.33333333 /, RAD / 57.295780 /, RHO0 / 1.225E-3 /
C
C      COMPUTE FRACTION OF TOTAL DUST LOFTED IN BASE CLOUD
       FBASE = RBASE / ( 1. + RBASE )
C
C      COMPUTE FRACTIONS OF THE MAIN DUST CLOUD MASS IN MODE A AND MODE B
C      PARTICLES
       FMBC = 1. / ( 1. + RMAB )
       FMAC = 1. - FMBC
C
C
C      LOOP OVER THE BURSTS
       DO 25 IW = 1, NW
C
C      COMPUTE TOTAL DUST MASS LOFTED IN MAIN CLOUD, ( DUST GRAINS ONLY,
C      NO WATER)
       TMASSD(IW) = 1.E6 * FCM(IW) * ( 1. - FH2O ) * ( 1. - FBASE ) *
      1             RHOD * ACV(IW) * W(IW) ** 1.111
C
C      COMPUTE TOTAL MASS OF CARBON IN MAIN CLOUD
```

```
      THASSC(IW) = 453.59 * ( 1. - FBASE ) * W(IW) * XLC
C
C     CALCULATE INITIAL RADIUS OF EQUIVALENT SPHERICAL CLOUD
      RI(IW) = 1.59 * ( W(IW) * FH(IW) * RHOO / RHOA ) ** THIRD
C
C     CALCULATE INITIAL RADII IN THE SHELL TRACK, CROSS TRACK AND THE
C     VERTICAL DIRECTIONS FOR THE MUNITION CLOUD
      RTI(IW) = CT(IW) * RI(IW)
      RPI(IW) = CP(IW) * RI(IW)
      RVI(IW) = CV(IW) * RI(IW)
C
C     CALCULATE IDEAL SPHERICAL CLOUD HORIZONTAL DIFFUSION CONSTANT
      XKS(IW) = ALPHA * SQRT( W(IW) * FH(IW) / ( ALPHA + 0.5 * CDRAG ) )
C
C     CALCULATE IDEAL SPHERICAL CLOUD RISE CONSTANT
      IF( ALPHA .GT. 1. ) GO TO 10
      FR(IW) = 5.31 / ALPHA ** 0.857
      GO TO 20
   10 FR(IW) = 5.31 / ALPHA ** 0.717
C
C     CALCULATE MUNITION CLOUD VERTICAL DIFFUSION CONSTANT
   20 XKV(IW) = 0.8464 * XKS(IW)
C
C     CALCULATE ANGLE ( IN RADIANS ) BETWEEN SHELL TRACK AND WIND TRACK
C     AZIMUTHS
      ASWRAD  = ( PHIBDG(IW) - PHIWDG ) / RAD
C
C     FIND INITIAL RADIUS OF HORIZONTAL ELLIPSE IN WIND TRACK AND CROSS
C     TRACK DIRECTIONS
      RTP = RTI(IW) * RPI(IW)
      SASWRD = SIN( ASWRAD )
      CASWRD = COS( ASWRAD )
      RTO(IW) = RTP / SQRT( ( RTI(IW) * SASWRD ) ** 2 + ( RPI(IW) *
     1          CASWRD ) ** 2 )
      RPO(IW) = RTP / SQRT( ( RTI(IW) * CASWRD ) ** 2 + ( RPI(IW) *
     1          SASWRD ) ** 2 )
C
   25 CONTINUE
C
C     FIND WIND VELOCITY COMPONENTS IN THE X AND Y DIRECTIONS
      PHIWRD = PHIWDG / RAD
      SINPW = SIN( PHIWRD )
      COSPW = COS( PHIWRD )
C
C     FIND THE WIND VELOCITY AT 10 METERS ALTITUDE
      VW10 = VWIND * ( 10. / ALTW ) ** PVW
C
      VW10X = VW10 * SINPW
      VW10Y = VW10 * COSPW
C
C     FIND THE WIND VELOCITY AT THE ALTITUDE OF THE INITIAL VERTICAL
C     RADIUS
C     CALCULATE THE TIME DELAYS BEFORE THE WIND BEGINS MOVING THE MAIN
C     AND BASE CLOUDS HORIZONTALLY
      DO 27 IW = 1, NW
      VWRVI(IW) = VWIND * ( RVI(IW) / ALTW ) ** PVW
      VWRVIX(IW) = VWRVI(IW) * SINPW
      VWRVIY(IW) = VWRVI(IW) * COSPW
```

```
      VRISE = FR(IM) * XKS(IM) / RI(IM)
      TOMAIN(IM) = 4. * RTO(IM) / SQRT( VM10 ** 2 + VRISE ** 2 )
      TOBASE(IM) = 4. * RTO(IM) / AMAX1( 0.1, VMRVI(IM) )
   27 CONTINUE
C
C     WRITE OUT THE INITIAL DATA
      WRITE(JTAPE, 30) ( ( IM, RI(IM), RTI(IM), RPI(IM), RVI(IM),
     1                  RTO(IM), RPO(IM), FR(IM), XKS(IM), XKV(IM) ),
     2                  IM = 1, NM )
   30 FORMAT(1H1//, 1H0,
     183H                                         GEOMETRIC PARAMETERS OF THE
     2 INITIAL DUST CLOUDS / 1H0,
     4120H        EQUIVALENT   RADIUS IN   RADIUS IN    RADIUS IN  RADIUS
     5 IN  RADIUS IN     SPHERICAL  SPHERICAL CLOUD  DUST CLOUD VER- /
     61H ,
     7124HBURST  SPHERICAL    SHELL TRACK SHELL CROSS  VERTICAL   WIND T
     8RACK WIND CROSS    CLOUD RISE DIFFUSION COEF-  TICAL DIFFUSION /
     91H ,
     1129HNUMBER CLOUD RADIUS DIRECTION   TRACK DIREC- DIRECTION  DIRECT
     2ION  TRACK DIREC-  CONSTANT   FICIENT            COEFFICIENT / 1H ,
     3122H         (METERS)      (METERS)   TION(METERS)  (METERS)   (METE
     4RS)  TION(METERS)                 (METERS2/S)          (METERS2/S)   /
     5( I3, F11.1, F13.1, F12.1, F12.1, F11.1, F12.1, F13.2, F13.2,
     6 F17.2 ) )
C
      WRITE(JTAPE, 40)
   40 FORMAT(1H0/ 1H0,
     179H                                          INITIAL DUST AND CARBON MA
     2SSES LOFTED (GM) / 1H0,
     3119HBURST                       MAIN CLOUD                          BASE
     4 CLOUD                                 TOTAL( MAIN + BASE CLOUD ) / 1H ,
     5130HNUMBER  DUST-MODE A  DUST-MODE B   CARBON    DUST-MODE A  DUST
     6-MODE B   CARBON     DUST-MODE A  DUST-MODE B    CARBON     SUM(A+B+
     7C) )
      DO 60 IM = 1, NM
      XMDA = FMAC * TMASSD(IM)
      XMDB = FMBC * TMASSD(IM)
      XMC = TMASSC(IM)
      BMDA = RBASE * XMDA
      BMDB = RBASE * XMDB
      BMC = RBASE * XMC
      TMDA = XMDA + BMDA
      TMDB = XMDB + BMDB
      TMC = XMC + BMC
      TM = TMDA + TMDB + TMC
      WRITE(JTAPE, 50) IM, XMDA, XMDB, XMC, BMDA, BMDB, BMC, TMDA, TMDB,
     1                 TMC, TM
   50 FORMAT(1H , I3, 2X, 1P2E13.2, E11.2, 2E13.2, E11.2, 2E13.2, E12.2,
     1       E11.2 )
   60 CONTINUE
C
      RETURN
      END
```

```
      SUBROUTINE TIMECO( T, IW )
C
C     THIS ROUTINE CALCULATES THE LOCATION AND CLOUD DIMENSIONS OF THE
C     ZERO DIAMETER PARTICLES IN THE MAIN AND BASE CLOUDS OF BURST IW AT
C     TIME T
C
C     INPUTS FROM CALL STATEMENT
C     T  = TIME AFTER BURST (S)
C     IW = BURST NUMBER
C
C     INPUTS FROM CINPT COMMON AREAS
C     ALTIV       = ALTITUDE ABOVE GROUND OF INVERSION LAYER (METERS)
C     XB(IW)      = X COORDINATE OF THE GROUND SURFACE AT BURST IW
C                   (METERS)
C     YB(IW)      = Y COORDINATE OF THE GROUND SURFACE AT BURST IW
C                   (METERS)
C     ZB(IW)      = Z COORDINATE OF THE GROUND SURFACE AT BURST IW
C                   (METERS)
C     PSF         = ATMOSPHERIC PASQUILL STABILITY FACTOR (1 = A, 2 = B,
C                   3 = C, 4 = D, 5 = E)
C
C     INPUTS FROM CINTG COMMON
C     RI(IW)   = INITIAL RADIUS OF THE EQUIVALENT SPHERICAL CLOUD FOR
C                BURST NUMBER IW (METERS)
C     RTI(IW) = DUST CLOUD INITIAL RADIUS IN THE SHELL TRACK DIRECTION
C                (METERS)
C     RPI(IW) = DUST CLOUD INITIAL RADIUS IN THE SHELL CROSS TRACK
C                DIRECTION (METERS)
C     RVI(IW) = DUST CLOUD INITIAL RADIUS IN THE VERTICAL DIRECTION
C                (METERS)
C     XKS(IW) = IDEAL SPHERICAL CLOUD HORIZONTAL DIFFUSION CONSTANT
C                (METERS2/S)
C     FR(IW)  = IDEAL SPHERICAL CLOUD RISE CONSTANT
C     XKV(IW) = DUST CLOUD VERTICAL DIFFUSION CONSTANT (METERS2/S)
C     RTO(IW) = INITIAL RADIUS OF DUST CLOUD IN WIND TRACK DIRECTION
C                (METERS)
C     RPO(IW) = INITIAL RADIUS OF DUST CLOUD IN WIND CTOSS TRACK
C                DIPECTION (METERS)
C     SINPW   = SINE OF THE WIND AZIMUTH ANGLE
C     COSPW   = COSINE OF THE WIND AZIMUTH ANGLE
C     VW10    = WIND VELOCITY AT 10 METERS ALTITUDE (METERS/S)
C     VW10X   = X COMPONENT OF THE WIND VELOCITY AT 10 METERS ALTITUDE
C                (METERS/S)
C     VW10Y   = Y COMPONENT OF THE WIND VELOCITY AT 10 METERS ALTITUDE
C                (METERS/S)
C     VWRVI(IW)  = WIND VELOCITY AT THE ALTITUDE OF THE INITIAL VERTICAL
C                   RADIUS OF BURST IW (METERS/S)
C     VWRVIX(IW) = X COMPONENT OF THE WIND VELOCITY AT THE ALTITUDE OF
C                   THE INITIAL VERTICAL RADIUS OF BURST IW ( METERS/S)
C     VWRVIY(IW) = Y COMPONENT OF THE WIND VELOCITY AT THE ALTITUDE OF
C                   THE INITIAL VERTICAL RADIUS OF BURST IW ( METERS/S)
C     TDMAIN(IW) = TIME DELAY BEFORE HORIZONTAL MOTION DUE TO WIND FOR
C                   THE MAIN DUST CLOUD OF BURST IW (SECONDS)
C     TDBASE(IW) = TIME DELAY BEFORE HORIZONTAL MOTION DUE TO WIND FOR
C                   THE BASE DUST CLOUD OF BURST IW (SECONDS)
C
C     OUTPUTS TO CTIME COMMON
C     XCENTO     = X COORDINATE OF THE CENTROID FOR ZERO DIAMETER
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C                     PARTICLES IN THE MAIN CLOUD (METERS)
C     YCENTO        = Y COORDINATE OF THE CENTROID FOR ZERO DIAMETER
C                     PARTICLES IN THE MAIN CLOUD (METERS)
C     ZCENTO        = Z COORDINATE OF THE CENTROID FOR ZERO DIAMETER
C                     PARTICLES IN THE MAIN CLOUD (METERS)
C     BXCNTO        = X COORDINATE OF THE CENTROID FOR ZERO DIAMETER
C                     PARTICLES IN THE BASE CLOUD (METERS)
C     BYCNTO        = Y COORDINATE OF THE CENTROID FOR ZERO DIAMETER
C                     PARTICLES IN THE BASE CLOUD (METERS)
C     BZCNTO        = Z COORDINATE OF THE CENTROID FOR ZERO DIAMETER
C                     PARTICLES IN THE BASE CLOUD (METERS)
C     RS            = RADIUS OF THE IDEAL SPHERICAL BUBBLE AT TIME T
C                     (METERS)
C     HS            = ALTITUDE ABOVE GROUND LEVEL OF THE CENTER OF THE
C                     IDEAL SPHERICAL BUBBLE (METERS)
C     RT            = RADIUS OF THE ZERO DIAMETER PARTICLES IN THE MAIN
C                     CLOUD  IN THE WIND TRACK DIRECTION (METERS)
C     RP            = RADIUS OF THE ZERO DIAMETER PARTICLES IN THE MAIN
C                     DIRECTION PERPENDICULAR TO THE WIND TRACK DIRECTION
C                     (METERS)
C     RV            = RADIUS OF THE ZERO DIAMETER PARTICLES IN THE MAIN
C                     CLOUD IN THE VERTICAL DIRECTION (METERS)
C     BRT           = RADIUS OF THE ZERO DIAMETER PARTICLES IN THE BASE
C                     CLOUD  IN THE WIND TRACK DIRECTION (METERS)
C     BRP           = RADIUS OF THE ZERO DIAMETER PARTICLES IN THE BASE
C                     DIRECTION PERPENDICULAR TO THE WIND TRACK DIRECTION
C                     (METERS)
C     BRV           = RADIUS OF THE ZERO DIAMETER PARTICLES IN THE BASE
C                     CLOUD IN THE VERTICAL DIRECTION (METERS)
C
      COMMON / CINPT1 / W(10), FH(10), CT(10), CP(10), CV(10), XB(10),
     1                  YB(10), ZB(10), DOB(10), FCM(10), ACV(10),
     2                  PHIBDG(10)
      COMMON / CINPTS / PSF, ALPHA, CDRAG, RHOA, ELEVG, TAIR, TLAPSE,
     1                  ALTIV, VWIND, ALTW, PVW, PHIWDG
      COMMON / CINITG / RI(10), RTI(10), RPI(10), RVI(10), XKS(10),
     1                  FR(10), XKV(10), RTO(10), RPO(10), SINPW, COSPW,
     2                  VW10, VW10X, VW10Y, VWRVI(10), VWRVIX(10),
     3                  VWRVIY(10), TMASSD(10), TMASSC(10), FMAC, FMBC,
     4                  POWER, TDMAIN(10), TDBASE(10)
      COMMON / CTIME / XCENTD, YCENTD, ZCENTD, XCENTC, YCENTC, ZCENTC,
     1                  RTD, RPD, RVD, RTC, RPC, RVC, RS, HS, RT, RP,
     2                  RV, XCENTO, YCENTO, ZCENTO, BXCNTD, BYCNTD,
     3                  BZCNTD, BXCNTC, BYCNTC, BZCNTC, BRTD, BRPD,
     4                  BRVD, BRTC, BRPC, BRVC, BXCNTO, BYCNTO, BZCNTO,
     5                  BRT, BRP, BRV
C
      DIMENSION BSZ(6), BCZ(6), BCXY(6)
      DATA BSZ / 0.90, 0.85, 0.80, 0.76, 0.73, 0.67 /,
     1     BCZ / 0.5675, 0.4266, 0.3988, 0.3282, 0.2093, 0.1279 /,
     2    BCXY / 30., 22.5, 15., 10., 7.5, 5.  /, RAD / 57.296 /,
     3     BMR / 3. /
C
C     MAIN CLOUD
C
C     FIND THE RADIUS AND ALTITUDE OF THE IDEAL SPHERICAL BUBBLE
      RS = SQRT( 2. * XKS(IW) * T + RI(IW) ** 2 )
      HS = RVI(IW) + FR(IW) * ( RS - RI(IW) )
```

```
      C
      C     LIMIT RISE ALTITUDE TO ALTITUDE OF INVERSION LAYER
            IF( HS .GT. ALTIV ) HS = ALTIV
      C
      C     FOR THIS TIME AND BURST, FIND THE CENTROID COORDINATES OF THE ZERO
      C     DIAMETER PARTICLES
            TM = AMAX1( 0., T - TDMAIN(IW) )
            XCENTO = XB(IW) + VW10X * TM
            YCENTO = YB(IW) + VW10Y * TM
            ZCENTO = ZB(IW) + HS
      C
      C     FIND THE RADII OF THE ZERO DIAMETER PARTICLES IN THE WIND TRACK,
      C     CROSS TRACK AND VERTICAL DIRECTIONS
            RT = SQRT( 8. * XKV(IW) * T + RTO(IW) ** 2 )
            RP = SQRT( 8. * XKV(IW) * T + RPO(IW) ** 2 )
            RV = SQRT( 2. * XKV(IW) * T + RVI(IW) ** 2 )
      C
      C     BASE CLOUD
            TB = AMAX1( 0., T - TDBASE(IW) )
            BXCNTO = XB(IW) + VWRVIX(IW) * TB
            BYCNTO = YB(IW) + VWRVIY(IW) * TB
            BZCNTO = ZB(IW) + RVI(IW)
      C
      C     INDEX OF PASQUILL STABILITY CATEGORY
            IPSF = IFIX( PSF )
            S = BSZ(IPSF)
            S1 = 1. / S
            POWER = S / ( 4. * S - 2. )
            DIST = VWRVI(IW) * T
            BRT = BHR * RTO(IW) + BCXY(IPSF) * DIST / RAD
            BRP = BHR * RPO(IW) + BCXY(IPSF) * DIST / RAD
            BRV = ( RVI(IW) ** S1 + BCZ(IPSF) * DIST ) ** S
      C
            RETURN
            END
```

```
      SUBROUTINE TIMECG( T, IW, IDG )
C
C     THIS ROUTINE CALCULATES THE GEOMETRIC PARAMETERS OF SIZE GROUP IDG
C     AT TIME T FOR BURST NUMBER IW
C
C     INPUTS FROM CALL STATEMENT
C     T   = TIME AFTER BURST (S)
C     IW  = BURST NUMBER
C     IDG = NUMBER OF THE SIZE GROUP
C
C     INPUTS FROM CINPT COMMON AREAS
C     RHOA         = AMBIENT AIR DENSITY AT GROUND LEVEL (GM/CM3)
C     RHOD         = BULK DENSITY OF THE LOFTED DUST GRAINS (GM/CM3)
C     RHOC         = BULK DENSITY OF THE CARBON PARTICLES (GM/CM3)
C     DGROUP(IDG)= MAXIMUM DIAMETER OF THE PARTICLES IN THE IDG SIZE
C                  GROUP (MICRONS)
C     ZB(IW)       = Z COORDINATE OF THE GROUND SURFACE AT BURST IW
C                    (METERS)
C
C     INPUTS FROM CINITG COMMON
C     RI(IW)   = INITIAL RADIUS OF THE EQUIVALENT SPHERICAL CLOUD FOR
C                BURST NUMBER IW (METERS)
C     RVI(IW) = DUST CLOUD INITIAL RADIUS IN THE VERTICAL DIRECTION
C                (METERS)
C     XKS(IW) = IDEAL SPHERICAL CLOUD HORIZONTAL DIFFUSION CONSTANT
C                (METERS2/S)
C     FR(IW)   = IDEAL SPHERICAL CLOUD RISE CONSTANT
C     XKV(IW) = DUST CLOUD VERTICAL DIFFUSION CONSTANT (METERS2/S)
C     RTO(IW) = INITIAL RADIUS OF DUST CLOUD IN WIND TRACK DIRECTION
C                (METERS)
C     RPO(IW) = INITIAL RADIUS OF DUST CLOUD IN WIND CTOSS TRACK
C                DIRECTION (METERS)
C     SINPW   = SINE OF THE WIND AZIMUTH ANGLE
C     COSPW   = COSINE OF THE WIND AZIMUTH ANGLE
C     VW10    = WIND VELOCITY AT 10 METERS ALTITUDE (METERS/S)
C     VWRVI(IW)  = WIND VELOCITY AT THE ALTITUDE OF THE INITIAL VERTICAL
C                  RADIUS OF BURST IW (METERS/S)
C     TDMAIN(IW) = TIME DELAY BEFORE HORIZONTAL MOTION DUE TO WIND FOR
C                  THE MAIN DUST CLOUD OF BURST IW (SECONDS)
C     TDBASE(IW) = TIME DELAY BEFORE HORIZONTAL MOTION DUE TO WIND FOR
C                  THE BASE DUST CLOUD OF BURST IW (SECONDS)
C
C     INPUTS FROM CTIME COMMON
C     XCENTO      = X COORDINATE OF THE CENTROID FOR ZERO DIAMETER
C                   PARTICLES IN THE MAIN CLOUD (METERS)
C     YCENTO      = Y COORDINATE OF THE CENTROID FOR ZERO DIAMETER
C                   PARTICLES IN THE MAIN CLOUD (METERS)
C     ZCENTO      = Z COORDINATE OF THE CENTROID FOR ZERO DIAMETER
C                   PARTICLES IN THE MAIN CLOUD (METERS)
C     BXCNTO      = X COORDINATE OF THE CENTROID FOR ZERO DIAMETER
C                   PARTICLES IN THE BASE CLOUD (METERS)
C     BYCNTO      = Y COORDINATE OF THE CENTROID FOR ZERO DIAMETER
C                   PARTICLES IN THE BASE CLOUD (METERS)
C     BZCNTO      = Z COORDINATE OF THE CENTROID FOR ZERO DIAMETER
C                   PARTICLES IN THE BASE CLOUD (METERS)
C     RS          = RADIUS OF THE IDEAL SPHERICAL BUBBLE AT TIME T
C                   (METERS)
C     HS          = ALTITUDE ABOVE GROUND LEVEL OF THE CENTER OF THE
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C                 IDEAL SPHERICAL BUBBLE (METERS)
C     RT        = RADIUS OF THE ZERO DIAMETER PARTICLES IN THE MAIN
C                 CLOUD  IN THE WIND TRACK DIRECTION (METERS)
C     RP        = RADIUS OF THE ZERO DIAMETER PARTICLES IN THE MAIN
C                 DIRECTION PERPENDICULAR TO THE WIND TRACK DIRECTION
C                 (METERS)
C     RV        = RADIUS OF THE ZERO DIAMETER PARTICLES IN THE MAIN
C                 CLOUD IN THE VERTICAL DIRECTION (METERS)
C     BRT       = RADIUS OF THE ZERO DIAMETER PARTICLES IN THE BASE
C                 CLOUD  IN THE WIND TRACK DIRECTION (METERS)
C     BRP       = RADIUS OF THE ZERO DIAMETER PARTICLES IN THE BASE
C                 DIRECTION PERPENDICULAR TO THE WIND TRACK DIRECTION
C                 (METERS)
C     BRV       = RADIUS OF THE ZERO DIAMETER PARTICLES IN THE BASE
C                 CLOUD IN THE VERTICAL DIRECTION (METERS)
C
C     OUTPUTS TO CTIME COMMON
C     XCENTD = X COORDINATE OF THE CENTROID FOR DUST PARTICLES (BOTH
C              MODE A AND MODE B) FOR THE MAIN CLOUD IN SIZE GROUP
C              IDG FOR BURST NUMBER IW AT TIME T (METERS)
C     YCENTD = Y COORDINATE OF THE CENTROID FOR DUST PARTICLES IN SIZE
C              GROUP IDG FOR BURST IW AT TIME T (METERS)
C     ZCENTD = Z COORDINATE OF THE CENTROID FOR DUST PARTICLES IN SIZE
C              GROUP IDG FOR BURST IW AT TIME T (METERS)
C     XCENTC = X COORDINATE OF THE CENTROID FOR CARBON PARTICLES IN SIZE
C              GROUP IDG FOR BURST IW AT TIME T (METERS)
C     YCENTC = Y COORDINATE OF THE CENTROID FOR CARBON PARTICLES IN SIZE
C              GROUP IDG FOR BURST IW AT TIME T (METERS)
C     ZCENTC = Z COORDINATE OF THE CENTROID FOR CARBON PARTICLES IN SIZE
C              GROUP IDG FOR BURST IW AT TIME T (METERS)
C     RTD    = RADIUS IN THE WIND TRACK DIRECTION FOR DUST PARTICLES IN
C              THE MAIN CLOUD IN SIZE GROUP IDG FOR BURST IW AT TIME T
C              (METERS)
C     RPD    = RADIUS IN THE DIRECTION PERPENDICULAR TO WIND TRACK
C              DIRECTION FOR DUST PARTICLES IN SIZE GROUP IDG FOR BURST
C              IW AT TIME T (METERS)
C     RVD    = RADIUS IN THE VERTICAL DIRECTION FOR DUST PARTICLES IN
C              SIZE GROUP IDG FOR BURST IW AT TIME T (METERS)
C     RTC    = RADIUS IN THE WIND TRACK DIRECTION FOR CARBON PARTICLES
C              IN SIZE GROUP IDG FOR BURST IW AT TIME T (METERS)
C     RPC    = RADIUS IN THE DIRECTION PERPENDICULAR TO THE WIND TRACK
C              DIRECTION FOR CARBON PARTICLES IN SIZE GROUP IDG FOR
C              BURST IW AT TIME T (METERS)
C     RVC    = RADIUS IN THE VERTICAL DIRECTION FOR CARBON PARTICLES IN
C              SIZE GROUP IDG FOR BURST IW AT TIME T (METERS)
C     BXCNTD = X COORDINATE OF THE BASE CLOUD CENTROID FOR DUST
C              PARTICLES (BOTH MODE A AND MODE B) FOR SIZE GROUP IDG FOR
C              BURST NUMBER IW AT TIME T (METERS)
C     BYCNTD = Y COORDINATE OF THE BASE CLOUD CENTROID FOR DUST
C              PARTICLES FOR SIZE GROUP IDG FOR BURST IW AT TIME T
C              (METERS)
C     BZCNTD = Z COORDINATE OF THE BASE CLOUD CENTROID FOR DUST
C              PARTICLES FOR SIZE GROUP IDG FOR BURST IW AT TIME T
C              (METERS)
C     BXCNTC = X COORDINATE OF THE BASE CLOUD CENTROID FOR CARBON
C              PARTICLES FOR SIZE GROUP IDG FOR BURST IW AT TIME T
C              (METERS)
C     BYCNTC = Y COORDINATE OF THE BASE CLOUD CENTROID FOR CARBON
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```
C                 PARTICLES FOR SIZE GROUP IDG FOR BURST IW AT TIME T
C                 (METERS)
C        BZCNTC = Z COORDINATE OF THE BASE CLOUD CENTROID FOR CARBON
C                 PARTICLES FOR SIZE GROUP IDG FOR BURST IW AT TIME T
C                 (METERS)
C        BRTD   = RADIUS IN THE WIND TRACK DIRECTION FOR THE BASE CLOUD
C                 DUST PARTICLES IN SIZE GROUP IDG FOR BURST IW AT TIME T
C                 (METERS)
C        BRPD   = RADIUS IN THE DIRECTION PERPENDICULAR TO THE WIND TRACK
C                 DIRECTION FOR THE BASE CLOUD DUST PARTICLES IN SIZE GROUP
C                 IDG FOR BURST IW AT TIME T (METERS)
C        BRVD   = RADIUS IN THE VERTICAL DIRECTION FOR THE BASE CLOUD DUST
C                 PARTICLES IN SIZE GROUP IDG FOR BURST IW AT TIME T
C                 (METERS)
C        BRTC   = RADIUS IN THE WIND TRACK DIRECTION FOR THE BASE CLOUD
C                 CARBON PARTICLES IN SIZE GROUP IDG FOR BURST IW AT TIME T
C                 (METERS)
C        BRPC   = RADIUS IN THE DIRECTION PERPENDICULAR TO THE WIND TRACK
C                 DIRECTION FOR THE BASE CLOUD CARBON PARTICLES IN SIZE
C                 GROUP IDG FOR BURST IW AT TIME T (METERS)
C        BRVC   = RADIUS IN THE VERTICAL DIRECTION FOR THE BASE CLOUD
C                 CARBON PARTICLES IN SIZE GROUP IDG FOR BURST IW AT TIME T
C                 (METERS)
C
         COMMON / CINPT1 / W(10), FH(10), CT(10), CF(10), CV(10), XB(10),
     1                     YB(10), ZB(10), DUR(10), FCM(10), ACV(10),
     2                     PHIBDG(10)
         COMMON / CINPT4 / RHOG, RHOD, RHOC, FH2O, XLC, RMAB, RBASE
         COMMON / CINPT5 / RSF, ALPHA, CDRAG, RHOA, ELEVG, TAIR, TLAPSE,
     1                     ALTIV, VWIND, ALTW, PVW, PHIWDG
         COMMON / CINPT7 / DGROUP(50), TIME(25)
         COMMON / CINITG / RI(10), RTI(10), RPI(10), RVI(10), XKS(10),
     1                     FR(10), XKV(10), RTO(10), RPO(10), SINPW, COSPW,
     2                     VW10, VW10X, VW10Y, VWRVI(10), VWRVIX(10),
     3                     VWRVIY(10), TMASSD(10), TMASSC(10), FMAC, FMBC,
     4                     POWER, TOMAIN(10), TDBASE(10)
         COMMON / CTIME / XCENTD, YCENTD, ZCENTD, XCENTC, YCENTC, ZCENTC,
     1                     RTD, RPD, RVD, RTC, RPC, RVC, RS, HS, RT, RP,
     2                     RV, XCENTO, YCENTO, ZCENTO, BXCNTD, BYCNTD,
     3                     BZCNTD, BXCNTC, BYCNTC, BZCNTC, BRTD, BRPD,
     4                     BRVD, BRTC, BRPC, BRVC, BXCNTO, BYCNTO, BZCNTO,
     5                     BRT, BRP, BRV
C
C        FIND INITIAL CLOUD RISE VELOCITY
         VRISE = FR(IW) * XKS(IW) / RI(IW)
C
C        CALCULATE TERMINAL VELOCITIES FOR DUST AND CARBON PARTICLES
         C3 = 48.87 / ( RHOA * DGROUP(IDG) )
         VTD = 1.E-2 * ( SQRT( C3 ** 2 + 0.2942 * RHOD * DGROUP(IDG) /
     1                         RHOA ) - C3 )
         VTC = 1.E-2 * ( SQRT( C3 ** 2 + 0.2942 * RHOC * DGROUP(IDG) /
     1                         RHOA ) - C3 )
C
C        CALCULATE C1 AND C2 CONSTANTS FOR HORIZONTAL CENTROID COORDINATES
         C1D = 1.E6 * RHOA / ( 3. * RHOD * DGROUP(IDG) )
         C1C = 1.E6 * RHOA / ( 3. * RHOC * DGROUP(IDG) )
         C2D = 3.258E5 / ( RHOD * DGROUP(IDG) ** 2 )
         C2C = 3.258E5 / ( RHOC * DGROUP(IDG) ** 2 )
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C
C     MAIN CLOUD CALCULATIONS
C
C     FIND Z COMPONENT OF CENTROID FOR DUST AND CARBON
      ZCENTD = ZB(IW) + ( ZCENTO - ZB(IW) ) *
     1       ( 1. - AMIN1( 1., VTD / VRISE ) ) - VTD * T
      ZCENTC = ZB(IW) + ( ZCENTO - ZB(IW) ) *
     1       ( 1. - AMIN1( 1., VTC / VRISE ) ) - VTC * T
C
C     CALCULATE DISTANCE THE SIZE GROUP HAS LAGGED BEHIND THE ZERO
C     DIAMETER GROUP
      DLAGD = 0.
      TM = AMAX1( 0., T - TDMAIN(IW) )
      IF( TM .LE. 0. ) GO TO 40
      C4 = C1D * VW10 / C2D
      IF( C2D * TM .GT. 20. ) GO TO 10
      DLAGD = ( ALOG( ( 1. + C4 ) * EXP( C2D * TM ) - C4 ) - C2D * TM )
     1 / C1D
      GO TO 20
   10 DLAGD = ALOG( 1. + C4 ) / C1D
   20 C4 = C1C * VW10 / C2C
      IF( C2C * TM .GT. 20. ) GO TO 30
      DLAGC = ( ALOG( ( 1. + C4 ) * EXP( C2C * TM ) - C4 ) - C2C * TM )
     1  / C1C
      GO TO 40
   30 DLAGC = ALOG( 1. + C4 ) / C1C
C
   40 XCENTD = XCENTO - DLAGD * SINPW
      YCENTD = YCENTO - DLAGD * COSPW
      XCENTC = XCENTO - DLAGC * SINPW
      YCENTC = YCENTO - DLAGC * COSPW
C
C     CALCULATE EFFECTIVE DIFFUSION COEFFICIENTS FOR THIS SIZE GROUP
      VH2 = VW10 ** 2 + VRISE ** 2
      XKVD = XKV(IW) / SQRT( 16. * VTD ** 2 / VH2 + 1. )
      XKVC = XKV(IW) / SQRT( 16. * VTC ** 2 / VH2 + 1. )
C
C     CALCULATE RADIUS OF SIZE GROUP IN VERTICAL, WIND TRACK AND CROSS
C     TRACK DIRECTIONS
      RVD = SQRT( 2. * XKVD * T + RVI(IW) ** 2 )
      RVC = SQRT( 2. * XKVC * T + RVI(IW) ** 2 )
      RTD = SQRT( 8. * XKVD * T + RTO(IW) ** 2 )
      RTC = SQRT( 8. * XKVC * T + RTO(IW) ** 2 )
      RPD = SQRT( 8. * XKVD * T + RPO(IW) ** 2 )
      RPC = SQRT( 8. * XKVC * T + RPO(IW) ** 2 )
C
C     BASE CLOUD CALCULATIONS
C
C     CENTROID LOCATIONS
C     FIND Z COMPONENT OF CENTROID FOR DUST AND CARBON
      BZCNTD = BZCNTO - VTD * T
      BZCNTC = BZCNTO - VTC * T
C
C     CALCULATE DISTANCE THE SIZE GROUP HAS LAGGED BEHIND THE ZERO
C     DIAMETER GROUP
      C4 = C1D * VWRVI(IW) / C2D
      DLAGC = 0.
      TB = AMAX1( 0., T - TDBASE(IW) )
```

```
      IF( TB .LE. 0. ) GO TO 80
      IF( C2D * TB .GT. 20. ) GO TO 50
      DLAGD = ( ALOG( ( 1. + C4 ) * EXP( C2D * TB ) - C4 ) - C2D * TB )
     1 / C1D
      GO TO 60
   50 DLAGD = ALOG( 1. + C4 ) / C1D
   60 C4 = C1C * VWRVI(IW) / C2C
      IF( C2C * TB .GT. 20. ) GO TO 70
      DLAGC = ( ALOG( ( 1. + C4 ) * EXP( C2C * TB ) - C4 ) - C2C * TB )
     1  / C1C
      GO TO 80
   70 DLAGC = ALOG( 1. + C4 ) / C1C
C
   80 BXCNTD = BXCNTO - DLAGD * SINpW
      BYCNTD = BYCNTO - DLAGD * COSpW
      BXCNTC = BXCNTO - DLAGC * SINpW
      BYCNTC = BYCNTO - DLAGC * COSpW
C
C     RADII OF SIZE GROUP
      DENOMD = 16. * VTD ** 2 / AMAx1 ( VWRVI(IW) ** 2, 1. ) + 1.
      DENOMC = 16. * VTC ** 2 / AMAx1( VWRVI(IW) ** 2, 1. ) + 1.
      BRTD = BRT / DENOMD
      BRTC = BRT / DENOMC
      BRPD = BRP / DENOMD
      BRPC = BRP / DENOMC
      BRVD = BRV / DENOMD ** POWER
      BRVC = BRV / DENOMC ** POWER
C
      RETURN
      END
```

```
      SUBROUTINE PATH( IW, IDG, IRT )
C
C     THIS ROUTINE COMPUTES THE MASSES PENETRATED (GM/CM2) ALONG THE
C     PATH BETWEEN RECEIVER AND TRANSMITTER NUMBER IRT DUE TO EACH
C     MATERIAL ( MODE A DUST, MODE B DUST AND CARBON ) IN SIZE GROUP
C     IDG FROM BURST IW
C
C     INPUTS FROM CALL STATEMENT
C     IW  = BURST NUMBER
C     IDG = SIZE GROUP NUMBER
C     IRT = RECEIVER - TRANSMITTER PAIR NUMBER
C
C     INPUTS FROM CINP1 COMMON AREAS
C     XR(IRT) = X COORDINATE OF RECEIVER NUMBER IRT (METERS)
C     YR(IRT) = Y COORDINATE OF RECEIVER NUMBER IRT (METERS)
C     ZR(IRT) = Z COORDINATE OF RECEIVER NUMBER IRT (METERS)
C     XT(IRT) = X COORDINATE OF TRANSMITTER NUMBER IRT (METERS)
C     YT(IRT) = Y COORDINATE OF TRANSMITTER NUMBER IRT (METERS)
C     ZT(IRT) = Z COORDINATE OF TRANSMITTER NUMBER IRT (METERS)
C     FCM(IW) = FRACTION OF APPARENT CRATER MASS LOFTED FOR BURST IW
C     ACV(IW) = APPARENT CRATER VOLUME SCALING FACTOR (M3/(LB TNT)1.111)
C     W(IW)   = YIELD OF BURST IW (LB TNT)
C     XLC     = LOADING FACTOR FOR CARBON ( RATIO OF THE WEIGHT OF
C               CARBON IN THE CLOUD TO THE YIELD WEIGHT )
C     RHOD    = BULK DENSITY OF SOIL (GM/CM3)
C     RHOC    = CARBON DENSITY (GM/CM3)
C     RBASE   = RATIO OF THE MASS IN THE BASE CLOUD TO THE MASS IN THE
C               MAIN CLOUD
C
C     INPUTS FROM CTIME COMMON
C     XCENTD = X COORDINATE OF THE CENTROID FOR DUST PARTICLES (BOTH
C              MODE A AND MODE B) FOR THE MAIN CLOUD IN SIZE GROUP
C              IDG FOR BURST NUMBER IW AT TIME T (METERS)
C     YCENTD = Y COORDINATE OF THE CENTROID FOR DUST PARTICLES IN SIZE
C              GROUP IDG FOR BURST IW AT TIME T (METERS)
C     ZCENTD = Z COORDINATE OF THE CENTROID FOR DUST PARTICLES IN SIZE
C              GROUP IDG FOR BURST IW AT TIME T (METERS)
C     XCENTC = X COORDINATE OF THE CENTROID FOR CARBON PARTICLES IN SIZE
C              GROUP IDG FOR BURST IW AT TIME T (METERS)
C     YCENTC = Y COORDINATE OF THE CENTROID FOR CARBON PARTICLES IN SIZE
C              GROUP IDG FOR BURST IW AT TIME T (METERS)
C     ZCENTC = Z COORDINATE OF THE CENTROID FOR CARBON PARTICLES IN SIZE
C              GROUP IDG FOR BURST IW AT TIME T (METERS)
C     RTD    = RADIUS IN THE WIND TRACK DIRECTION FOR DUST PARTICLES IN
C              THE MAIN CLOUD IN SIZE GROUP IDG FOR BURST IW AT TIME T
C              (METERS)
C     RPD    = RADIUS IN THE DIRECTION PERPENDICULAR TO WIND TRACK
C              DIRECTION FOR DUST PARTICLES IN SIZE GROUP IDG FOR BURST
C              IW AT TIME T (METERS)
C     RVD    = RADIUS IN THE VERTICAL DIRECTION FOR DUST PARTICLES IN
C              SIZE GROUP IDG FOR BURST IW AT TIME T (METERS)
C     RTC    = RADIUS IN THE WIND TRACK DIRECTION FOR CARBON PARTICLES
C              IN SIZE GROUP IDG FOR BURST IW AT TIME T (METERS)
C     RPC    = RADIUS IN THE DIRECTION PERPENDICULAR TO THE WIND TRACK
C              DIRECTION FOR CARBON PARTICLES IN SIZE GROUP IDG FOR
C              BURST IW AT TIME T (METERS)
C     RVC    = RADIUS IN THE VERTICAL DIRECTION FOR CARBON PARTICLES IN
C              SIZE GROUP IDG FOR BURST IW AT TIME T (METERS)
```

```
C      BXCNTD = X COORDINATE OF THE BASE CLOUD CENTROID FOR DUST
C                PARTICLES (BOTH MODE A AND MODE B) FOR SIZE GROUP IDG FOR
C                BURST NUMBER IN AT TIME T (METERS)
C      BYCNTD = Y COORDINATE OF THE BASE CLOUD CENTROID FOR DUST
C                PARTICLES FOR SIZE GROUP IDG FOR BURST IN AT TIME T
C                (METERS)
C      BZCNTD = Z COORDINATE OF THE BASE CLOUD CENTROID FOR DUST
C                PARTICLES FOR SIZE GROUP IDG FOR BURST IN AT TIME T
C                (METERS)
C      BXCNTC = X COORDINATE OF THE BASE CLOUD CENTROID FOR CARBON
C                PARTICLES FOR SIZE GROUP IDG FOR BURST IN AT TIME T
C                (METERS)
C      BYCNTC = Y COORDINATE OF THE BASE CLOUD CENTROID FOR CARBON
C                PARTICLES FOR SIZE GROUP IDG FOR BURST IN AT TIME T
C                (METERS)
C      BZCNTC = Z COORDINATE OF THE BASE CLOUD CENTROID FOR CARBON
C                PARTICLES FOR SIZE GROUP IDG FOR BURST IN AT TIME T
C                (METERS)
C      BRTD   = RADIUS IN THE WIND TRACK DIRECTION FOR THE BASE CLOUD
C                DUST PARTICLES IN SIZE GROUP IDG FOR BURST IN AT TIME T
C                (METERS)
C      BRPD   = RADIUS IN THE DIRECTION PERPENDICULAR TO THE WIND TRACK
C                DIRECTION FOR THE BASE CLOUD DUST PARTICLES IN SIZE GROUP
C                IDG FOR BURST IN AT TIME T (METERS)
C      BRVD   = RADIUS IN THE VERTICAL DIRECTION FOR THE BASE CLOUD DUST
C                PARTICLES IN SIZE GROUP IDG FOR BURST IN AT TIME T
C                (METERS)
C      BRTC   = RADIUS IN THE WIND TRACK DIRECTION FOR THE BASE CLOUD
C                CARBON PARTICLES IN SIZE GROUP IDG FOR BURST IN AT TIME T
C                (METERS)
C      BRPC   = RADIUS IN THE DIRECTION PERPENDICULAR TO THE WIND TRACK
C                DIRECTION FOR THE BASE CLOUD CARBON PARTICLES IN SIZE
C                GROUP IDG FOR BURST IN AT TIME T (METERS)
C      BRVC   = RADIUS IN THE VERTICAL DIRECTION FOR THE BASE CLOUD
C                CARBON PARTICLES IN SIZE GROUP IDG FOR BURST IN AT TIME T
C                (METERS)
C
C      INPUTS FROM CINITC COMMON
C      FMAC    = FRACTION OF MAIN CLOUD DUST MASS IN MODE A PARTICLES
C      FMBC    = FRACTION OF MAIN CLOUD DUST MASS IN MODE B PARTICLES
C      TMASSD(IN) = TOTAL INITIAL DUST MASS LOFTED IN MAIN CLOUD OF BURST
C                   IN (GM)
C      TMASSC(IN) = TOTAL INITIAL CARBON MASS LOFTED IN MAIN CLOUD OF
C                   BURST IN (GM)
C
C      INPUTS FROM CPGRP COMMON
C      FMA(I)     = MASS FRACTION FOR SIZE GROUP I FOR MODE A DUST
C                   PARTICLES ( RATIO OF MASS OF PARTICLES IN SIZE GROUP I
C                   TO TOTAL MASS IN DISTRIBUTION )
C      FMB(I)     = MASS FRACTION FOR SIZE GROUP I FOR MODE B DUST
C                   PARTICLES
C      FMC(I)     = MASS FRACTION FOR SIZE GROUP I FOR CARBON PARTICLES
C      CMUEA(I,J) = MASS EXTINCTION COEFFICIENT FOR SIZE GROUP I AT
C                   WAVELENGTH J FOR MODE A DUST PARTICLES (CM2/GM)
C      CMUEB(I,J) = MASS EXTINCTION COEFFICIENT FOR SIZE GROUP I AT
C                   WAVELENGTH J FOR MODE B DUST PARTICLES (CM2/GM)
C      CMUEC(I,J) = MASS EXTINCTION COEFFICIENT FOR SIZE GROUP I AT
C                   WAVELENGTH J FOR CARBON PARTICLES (CM2/GM)
```

```
C
C      OUTPUTS TO CPATH COMMON
C      PMASSA = MASS PENETRATED ALONG THE PATH BETWEEN RECEIVER AND
C                TRANSMITTER NUMBER IRT DUE TO MODE A DUST PARTICLES IN
C                SIZE GROUP IDG IN THE MAIN CLOUD OF BURST IN (GM/CM2)
C      PMASSB = MODE B DUST PARTICLE MASS PENETRATED (GM/CM2)
C      PMASSC = CARBON PARTICLE MASS PENETRATED (GM/CM2)
C      BPMASA = MASS PENETRATED ALONG THE PATH BETWEEN RECEIVER AND
C                TRANSMITTER NUMBER IRT DUE TO MODE A DUST PARTICLES IN
C                SIZE GROUP IDG IN THE BASE CLOUD OF BURST IN (GM/CM2)
C      BPMASB = MODE B DUST PARTICLE MASS PENETRATED (GM/CM2)
C      BPMASC = CARBON PARTICLE MASS PENETRATED (GM/CM2)
C      GMASSA = MASS OF MODE A DUST PARTICLES IN SIZE GROUP IDG IN
C                THE MAIN CLOUD OF BURST IN (GM)
C      GMASSB = MASS OF MODE B DUST PARTICLES IN SIZE GROUP IDG IN
C                THE MAIN CLOUD OF BURST IN (GM)
C      GMASSC = MASS OF CARBON PARTICLES IN SIZE GROUP IDG FROM BURST IN
C                IN THE MAIN CLOUD OF BURST IN (GM)
C      BGMASA = MASS OF MODE A DUST PARTICLES IN SIZE GROUP IDG IN
C                THE BASE CLOUD OF BURST IN (GM)
C      BGMASB = MASS OF MODE B DUST PARTICLES IN SIZE GROUP IDG IN
C                THE BASE CLOUD OF BURST IN (GM)
C      GMASSC = MASS OF CARBON PARTICLES IN SIZE GROUP IDG FROM BURST IN
C                IN THE BASE CLOUD OF BURST IN (GM)
C
       COMMON / CPGRP / FNA(50), FNB(50), FNC(50), FMA(50), FMB(50),
      1                 FMC(50), PNGA(50), PNGB(50), PNGC(50),
      2                 CMUSA(50,10), CMUSB(50,10), CMUSC(50,10),
      3                 CMUEA(50,10), CMUEB(50,10), CMUEC(50,10),
      4                 CMUBA(50,10), CMUBB(50,10), CMUBC(50,10)
       COMMON / CINPT1 / W(10), FH(10), CT(10), CP(10), CV(10), XB(10),
      1                  YB(10), ZB(10), COB(10), FCM(10), ACV(10),
      2                  PHIBDG(10)
       COMMON / CINPT2 / FREQ(10), XLAMDA(10), XT(10), YT(10), ZT(10),
      1                  XR(10), YR(10), ZR(10)
       COMMON / CINPT4 / RHOG, RHOD, RHOC, FH2O, XLC, RMAB, RBASE
       COMMON / CTIME / XCENTD, YCENTD, ZCENTD, XCENTC, YCENTC, ZCENTC,
      1                 RTD, RPD, RVD, RTC, RPC, RVC, RS, HS, RT, RP,
      2                 RV, XCENTO, YCENTO, ZCENTO, BXCNTD, BYCNTD,
      3                 BZCNTD, BXCNTC, BYCNTC, BZCNTC, BRTD, BRPD,
      4                 BRVD, BRTC, BRPC, BRVC, BXCNTO, BYCNTO, BZCNTO,
      5                 BRT, BRP, BRV
       COMMON / CINITG / RI(10), RTI(10), RPI(10), RVI(10), XKS(10),
      1                  FR(10), XKV(10), RTO(10), RPO(10), SINPH, COSPH,
      2                  VW10, VW10X, VW10Y, VWRVI(10), VWRVIX(10),
      3                  VWRVIY(10), TMASSD(10), TMASSC(10), FMAC, FMBC,
      4                  POWER, TOMAIN(10), TOBASE(10)
       COMMON / CPATH / PMASSA, PMASSB, PMASSC, GMASSA, GMASSB, GMASSC
      1                , BPMASA, BPMASB, BPMASC, BGMASA, BGMASB, BGMASC
C
C      SET VALUE OF RATIO OF GROUP SIZE RADIUS TO GROUP STANDARD
C      DEVIATION
       DATA CR / 2.15 /
C
       DIMENSION VECR(3), VECT(3), VECCEN(3), VECTCN(3), VECTR(3),
      1          VECBTR(3), VECINT(3), VECIC(3)
C
C      CHECK IF RECEIVER - TRANSMITTER LOCATIONS FOR THIS FREQUENCY ARE
```

```
C      THE SAME AS FOR THE PREVIOUS CALCULATION. IF THE SAME, SKIP THE
C      PATH INTEGRATION
       IF( IRT .EQ. 1 ) GO TO 30
       IRT1 = IRT - 1
       IF( XR(IRT) .NE. XR(IRT1) .OR. YR(IRT) .NE. YR(IRT1) .OR.
      1    ZR(IRT) .NE. ZR(IRT1) ) GO TO 30
       IF( XT(IRT) .NE. XT(IRT1) .OR. YT(IRT) .NE. YT(IRT1) .OR.
      1    ZT(IRT) .NE. ZT(IRT1) ) GO TO 30
       GO TO 200
C
C      SET VECTORS FOR RECEIVER AND TRANSMITTER LOCATIONS
    30 VECR(1) = XR(IRT)
       VECR(2) = YR(IRT)
       VECR(3) = ZR(IRT)
       VECT(1) = XT(IRT)
       VECT(2) = YT(IRT)
       VECT(3) = ZT(IRT)
C
C      LOOP OVER THE MATERIALS WITH DIFFERENT DENSITIES
       DO 190 ID = 1, 2
       IF( ID .EQ. 2 ) GO TO 35
C
C      MATERIAL IS DUST
C      CHECK IF SIZE GROUP HAS INSIGNIFICANT PROPAGATION EFFECT
       PMASSN = 0.
       BPMASN = 0.
       IF( CMUEA(IDG,IRT) .EQ. 0. .AND. CMUEB(IDG,IRT) .EQ. 0. )GO TO 170
       GO TO 40
C
C      MATERIAL IS CARBON, CHECK IF CARBON DENSITY IS THE SAME AS THE
C      DUST DENSITY. IF THE DENSITIES ARE THE SAME USE THE PREVIOUSLY
C      CALCULATED DUST NORMALIZED MASS PENETRATED VALUES(IF NONZERO)
    35 IF( RHOC .EQ. RHOD .AND. AMAX1( PMASSN, BPMASN ) .NE. 0. )
      1 GO TO 160
C
C      CHECK IF SIZE GROUP HAS INSIGNIFICANT PROPAGATION EFFECT
       PMASSN = 0.
       BPMASN = 0.
       IF( CMUEC(IDG,IRT) .EQ. 0. ) GO TO 160
C
C      FIRST FIND THE MASS PENETRATED FOR THE MAIN CLOUD, THEN FOR THE
C      BASE CLOUD
    40 DO 160 ICLOUD = 1, 2
C
C      SET VALUES FOR PARTICLE RADII AND CENTROID LOCATIONS
       IF( ID .EQ. 2 ) GO TO 50
C
C      SET THE DUST PARAMETERS FOR PATH INTEGRATION
       IF( ICLOUD .EQ. 2 ) GO TO 45
C
C      MAIN CLOUD
       RVCEN = RVD
       RTCEN = RTD
       RPCEN = RPD
       VECCEN(1) = XCENTD
       VECCEN(2) = YCENTD
       VECCEN(3) = ZCENTD
       GO TO 60
```

```
C
C     BASE CLOUD
   45 RVCEN = BRVD
      RTCEN = BRTD
      RPCEN = BRPD
      VECCEN(1) = BXCNTD
      VECCEN(2) = BYCNTD
      VECCEN(3) = BZCNTD
      GO TO 60
C
C     SET THE CARBON PARAMETERS FOR THE PATH INTEGRATION
   50 IF( ICLOUD .EQ. 2 ) GO TO 55
C
C     MAIN CLOUD
      RVCEN = RVC
      RTCEN = RTC
      RPCEN = RPC
      VECCEN(1) = XCENTC
      VECCEN(2) = YCENTC
      VECCEN(3) = ZCENTC
      GO TO 60
C
C     BASE CLOUD
   55 RVCEN = BRVC
      RTCEN = BRTC
      RPCEN = BRPC
      VECCEN(1) = BXCNTC
      VECCEN(2) = BYCNTC
      VECCEN(3) = BZCNTC
C
C
C     SET GAUSSIAN STANDARD DEVIATIONS, SET GAUSSIAN DENSITY CALCULATION
C     CONSTANT
   60 STANT = RTCEN / CR
      STANP = RPCEN / CR
      STANV = RVCEN / CR
      STAN = AMAX1( STANT, STANP )
      CONSTI = 6.3493939E-8 / ( STANT * STANP * STANV )
C
C     FIND THE POINT OF CLOSEST APPROACH OF THE PATH TO THE CENTROID
C     LOCATION
      CALL SUBVEC( VECT, VECCEN, VECTCN )
      CALL SUBVEC( VECT, VECR, VECTR )
      CALL DOTVEC( VECTR, VECTR, TR2 )
      CALL DOTVEC( VECTCN, VECTR, TCTR )
      BETA = TCTR / TR2
C
C     CHECK IF GROUP CENTROID IS MORE THAN 5 STANDARD DEVIATIONS FROM
C     THE POINT OF CLOSEST APPROACH. IF IT IS, SKIP INTEGRATION
      CALL DOTVEC( VECTCN, VECTCN, DTCN2 )
      DCP = SQRT( DTCN2 - TR2 * BETA ** 2 )
      IF( DCP / STAN .GT. 5. ) GO TO 160
C
C     IF POINT OF CLOSEST APPROACH IS OUTSIDE ENDPOINTS OF PATH
C     INTEGRATION, SET TO NEAREST PATH ENDPOINT
      IF( BETA .LT. 0. ) BETA = 0.
      IF( BETA .GT. 1. ) BETA = 1.
C
```

```
C     INTEGRATION STRATEGY - START AT POINT OF CLOSEST APPROACH,
C     INTEGRATE FORWARD TO THE FIRST ENDPOINT, THEN  BACKWARDS TO THE
C     SECOND ENDPOINT. STOP INTEGRATION IF DISTANCE FROM INTEGRATION
C     POINT TO GROUP CENTROID POINT EXCEEDS 5 STANDARD DEVIATIONS
C     WE USE A SIMPSONS RULE INTEGRATION WITH STEP SIZES OF ABOUT 0.2
C     OF THE LARGEST OF THE THREE GAUSSIAN STANDARD DEVIATIONS
C
C     FIND TOTAL PATH LENGTH BETWEEN RECEIVER AND TRANSMITTER
      CALL DSTVEC( VECT, VECR, DRT )
C
C     INTEGRATE FORWARDS AND BACKWARDS FROM POINT OF CLOSEST APPROACH
      DO 150 INT = 1, 2
      IF( INT .EQ. 2 ) GO TO 70
C
C     FORWARD INTEGRATION SEGMENT. INTEGRATE FROM CLOSEST APPROACH POINT
C     TO RECEIVER
C
C     SET STEP SIZE
      DIR = DRT * ( 1. - BETA )
      NSTEP = IFIX( 5. * DIR / STAN )
      DBETA = ( 1. - BETA ) / FLOAT( NSTEP )
      IF( NSTEP .EQ. 0 ) GO TO 170
      IF( MOD( NSTEP, 2 ) .EQ. 1 ) NSTEP = NSTEP + 1
      GO TO 80
C
C     SECOND HALF OF INTEGRATION. INTEGRATE FROM POINT OF CLOSEST
C     APPROACH TO TRANSMITTER
   70 DIT = DRT * BETA
      NSTEP = IFIX( 5. * DIT / STAN )
      IF( NSTEP .EQ. 0 ) GO TO 170
      IF( MOD( NSTEP, 2 ) .EQ. 1 ) NSTEP = NSTEP + 1
      DBETA = - BETA / FLOAT( NSTEP )
C
   80 IGO = 1
      SUM = 0.
      BETAI = BETA - DBETA
C
      DO 120 ISTEP = 1, NSTEP
      BETAI = BETAI + DBETA
C
C     FIND VECTOR TO INTEGRATION POINT
      CALL MULVEC( VECTR, - BETAI, VECBTR )
      CALL ADDVEC( VECT, VECBTR, VECINT )
C
C     FIND PROJECTIONS OF THE VECTOR FROM THE CENTROID TO THE
C     INTEGRATION POINT IN THE TRACK, CROSS TRACK, AND VERTICAL
C     DIRECTIONS
      CALL SUBVEC( VECINT, VCCCEN, VECIC )
      PROJV = VECIC(3)
      PROJT = VECIC(1) * SINPW + VECIC(2) * COSPW
      PROJP = VECIC(1) * COSPW - VECIC(2) * SINPW
C
C     CHECK IF DISTANCE FROM INTEGRATION POINT TO CENTROID IS MORE THAN
C     5 STANDARD DEVIATIONS. IF SO, STOP THIS PORTION OF THE INTEGRATION
      SDEV = 0.5 * ( ( PROJT / STANT ) ** 2 + ( PROJP / STANP ) ** 2
     1     + ( PROJV / STANV ) ** 2 )
      IF( SDEV .GT. 12.5 ) GO TO 130
C
```

```
C     ASSUMING UNIT MASS IN THE SIZE GROUP, CALCULATE EXPONENT FACTOR
C     OF THE GAUSSIAN DENSITY AT THE INTEGRATION POINT
      EXPF = EXP( - SDEV )
C
      IF( ISTEP .EQ. NSTEP ) GO TO 90
      GO TO( 90, 100, 110 ), IGO
   90 SUM = SUM + EXPF
      IGO = 2
      GO TO 120
  100 SUM = SUM + 4. * EXPF
      IGO = 3
      GO TO 120
  110 SUM = SUM + 2. * EXPF
      IGO = 2
  120 CONTINUE
C
C     THIS PHASE OF INTEGRATION COMPLETED, SET CONTRIBUTION
  130 IF( INT .EQ. 2 ) GO TO 140
C
C     SET NORMALIZED PENETRATED MASS ( GM / CM2 ) CONTRIBUTION FROM
C     FIRST INTEGRATION
      IF( ICLOUD .EQ. 2 ) GO TO 135
      PMASSN = 100. * SUM * CONSTI * DBETA * DRT / 3.
      GO TO 150
  135 BPMASN = 100. * SUM * CONSTI * DBETA * DRT / 3.
      GO TO 150
C
C     ADD NORMALIZED PENETRATED MASS CONTRIBUTION FROM SECOND HALF OF
C     PATH INTEGRATION
  140 IF( ICLOUD .EQ. 2 ) GO TO 145
      PMASSN = PMASSN - 100. * SUM * CONSTI * DBETA * DRT / 3.
      GO TO 150
  145 BPMASN = BPMASN - 100. * SUM * CONSTI * DBETA * DRT / 3.
C
  150 CONTINUE
C
  160 CONTINUE
C
C     NORMALIZED PENETRATED MASS INTEGRATION COMPLETED
      IF( IO .EQ. 2 ) GO TO 180
C
C     COMPUTE MAIN CLOUD DUST MASSES IN SIZE GROUP
  170 GMASSA = FMAC * TMASSD(IM) * FMA(IDG)
      GMASSB = FMBC * TMASSD(IM) * FMB(IDG)
C
C     COMPUTE THE ACTUAL MAIN CLOUD DUST MASS PENETRATED FOR THIS SIZE
C     GROUP
      PMASSA = GMASSA * PMASSN
      PMASSB = GMASSB * PMASSN
C
C     COMPUTE DUST MASS PARAMETERS FOR THE BASE CLOUD
      BGMASA = RBASE * GMASSA
      BGMASB = RBASE * GMASSB
      BPMASA = BGMASA * BPMASN
      BPMASB = BGMASB * BPMASN
      GO TO 190
C
C     COMPUTE MAIN CLOUD CARBON MASS IN GROUP
```

```
  180 GMASSC = FMC(IDG) * TMASSC(IM)
C
C     COMPUTE ACTUAL MAIN CLOUD CARBON MASS PENETRATED FOR THIS SIZE
C     GROUP
      PMASSC = GMASSC * PMASSN
C
C     COMPUTE CARBON MASS PARAMETERS FOR THE BASE CLOUD
      BGMASC = RBASC * GMASSC
      BPMASC = BGMASC * BPMASN
C
  190 CONTINUE
C
  200 RETURN
      END
```

```
      SUBROUTINE DEPTH( T, IW, IDG, IRT )
C
C     THIS ROUTINE CALCULATES THE OPTICAL DEPTHS FOR EXTINCTION,
C     SCATTERING AND ABSORPTION FOR THE GIVEN TIME, BURST, SIZE GROUP,
C     AND RECEIVER - TRANSMITTER PATH. THIS ROUTINE ALSO WRITES OUT THE
C     DETAILED AND SUMMARY TIME DEPENDENT RESULTS
C
C     INPUTS FROM CALL STATEMENT
C     T   = TIME AFTER BURST (S)
C     IW  = BURST NUMBER
C     IDG = SIZE GROUP NUMBER
C     IRT = TRANSMITTER - RECEIVER PAIR NUMBER
C
C     INPUTS FROM CINPT COMMON AREAS
C     NW          = NUMBER OF BURSTS
C     NDG         = NUMBER OF PARTICLE DIAMETER SIZE GROUPS
C     NRT         = NUMBER OF TRANSMITTER - RECEIVER PAIRS
C     NPROB       = NUMBER OF THE PRESENT CASE BEING CALCULATED
C     IPRINT      = PRINT CONTROL OPTION (0 = PRINT DETAILS OF PATH
C                   INTEGRATION, 1 = PRINT ONLY SUMMARY OF THE PATH
C                   INTEGRATION)
C     FREQ(IRT)   = FREQUENCY OF TRANSMITTER - RECEIVER PAIR IRT (GHZ)
C     XLAMDA(IRT)= WAVELENGTH OF TRANSMITTER - RECEIVER PAIR IRT
C                   (MICRONS)
C     XT(IRT)     = X COORDINATE OF TRANSMITTER IRT (METERS)
C     YT(IRT)     = Y COORDINATE OF TRANSMITTER IRT (METERS)
C     ZT(IRT)     = Z COORDINATE OF TRANSMITTER IRT (METERS)
C     XR(IRT)     = X COORDINATE OF RECEIVER IRT (METERS)
C     YR(IRT)     = Y COORDINATE OF RECEIVER IRT (METERS)
C     ZR(IRT)     = Z COORDINATE OF RECEIVER IRT (METERS)
C
C     INPUTS FROM CPATH COMMON
C     PMASSA = MASS PENETRATED ALONG THE PATH BETWEEN RECEIVER AND
C              TRANSMITTER NUMBER IRT DUE TO MODE A DUST PARTICLES IN
C              SIZE GROUP IDG FROM BURST IW (GM/CM2)
C     PMASSB = MODE B DUST PARTICLE MASS PENETRATED (GM/CM2)
C     PMASSC = CARBON PARTICLE MASS PENETRATED (GM/CM2)
C     GMASSA = MASS OF MODE A DUST PARTICLES IN SIZE GROUP IDG AT TIME
C              T DUE TO BURST IW (GM)
C     GMASSB = MASS OF MODE B DUST PARTICLES IN SIZE GROUP IDG AT TIME
C              T DUE TO BURST IW (GM)
C     GMASSC = MASS OF CARBON PARTICLES IN SIZE GROUP IDG AT TIME T DUE
C              TO BURST IW (GM)
C
C     INPUTS FROM CPGRP COMMON
C     CMUSA(I,J) = MASS SCATTERING COEFFICIENT FOR SIZE GROUP I AT
C                  WAVELENGTH J FOR MODE A DUST PARTICLES (CM2/GM)
C     CMUSB(I,J) = MASS SCATTERING COEFFICIENT FOR SIZE GROUP I AT
C                  WAVELENGTH J FOR MODE B DUST PARTICLES (CM2/GM)
C     CMUSC(I,J) = MASS SCATTERING COEFFICIENT FOR SIZE GROUP I AT
C                  WAVELENGTH J FOR CARBON PARTICLES (CM2/GM)
C     CMUEA(I,J) = MASS EXTINCTION COEFFICIENT FOR SIZE GROUP I AT
C                  WAVELENGTH J FOR MODE A DUST PARTICLES (CM2/GM)
C     CMUEB(I,J) = MASS EXTINCTION COEFFICIENT FOR SIZE GROUP I AT
C                  WAVELENGTH J FOR MODE B DUST PARTICLES (CM2/GM)
C     CMUEC(I,J) = MASS EXTINCTION COEFFICIENT FOR SIZE GROUP I AT
C                  WAVELENGTH J FOR CARBON PARTICLES (CM2/GM)
C
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C     INPUTS FROM CTIME COMMON (USED ONLY FOR PRINTING DETAILED RESULTS)
C     XCENTO = X COORDINATE OF THE CENTROID FOR DUST PARTICLES (BOTH
C              MODE A AND MODE B) FOR THE MAIN CLOUD IN SIZE GROUP
C              IDG FOR BURST NUMBER IN AT TIME T (METERS)
C     YCENTO = Y COORDINATE OF THE CENTROID FOR DUST PARTICLES IN SIZE
C              GROUP IDG FOR BURST IN AT TIME T (METERS)
C     ZCENTO = Z COORDINATE OF THE CENTROID FOR DUST PARTICLES IN SIZE
C              GROUP IDG FOR BURST IN AT TIME T (METERS)
C     XCENTC = X COORDINATE OF THE CENTROID FOR CARBON PARTICLES IN SIZE
C              GROUP IDG FOR BURST IN AT TIME T (METERS)
C     YCENTC = Y COORDINATE OF THE CENTROID FOR CARBON PARTICLES IN SIZE
C              GROUP IDG FOR BURST IN AT TIME T (METERS)
C     ZCENTC = Z COORDINATE OF THE CENTROID FOR CARBON PARTICLES IN SIZE
C              GROUP IDG FOR BURST IN AT TIME T (METERS)
C     RTD    = RADIUS IN THE WIND TRACK DIRECTION FOR DUST PARTICLES IN
C              THE MAIN CLOUD IN SIZE GROUP IDG FOR BURST IN AT TIME T
C              (METERS)
C     RPD    = RADIUS IN THE DIRECTION PERPENDICULAR TO WIND TRACK
C              DIRECTION FOR DUST PARTICLES IN SIZE GROUP IDG FOR BURST
C              IN AT TIME T (METERS)
C     RVD    = RADIUS IN THE VERTICAL DIRECTION FOR DUST PARTICLES IN
C              SIZE GROUP IDG FOR BURST IN AT TIME T (METERS)
C     RTC    = RADIUS IN THE WIND TRACK DIRECTION FOR CARBON PARTICLES
C              IN SIZE GROUP IDG FOR BURST IN AT TIME T (METERS)
C     RPC    = RADIUS IN THE DIRECTION PERPENDICULAR TO THE WIND TRACK
C              DIRECTION FOR CARBON PARTICLES IN SIZE GROUP IDG FOR
C              BURST IN AT TIME T (METERS)
C     RVC    = RADIUS IN THE VERTICAL DIRECTION FOR CARBON PARTICLES IN
C              SIZE GROUP IDG FOR BURST IN AT TIME T (METERS)
C     BXCNTD = X COORDINATE OF THE BASE CLOUD CENTROID FOR DUST
C              PARTICLES (BOTH MODE A AND MODE B) FOR SIZE GROUP IDG FOR
C              BURST NUMBER IN AT TIME T (METERS)
C     BYCNTD = Y COORDINATE OF THE BASE CLOUD CENTROID FOR DUST
C              PARTICLES FOR SIZE GROUP IDG FOR BURST IN AT TIME T
C              (METERS)
C     BZCNTD = Z COORDINATE OF THE BASE CLOUD CENTROID FOR DUST
C              PARTICLES FOR SIZE GROUP IDG FOR BURST IN AT TIME T
C              (METERS)
C     BXCNTC = X COORDINATE OF THE BASE CLOUD CENTROID FOR CARBON
C              PARTICLES FOR SIZE GROUP IDG FOR BURST IN AT TIME T
C              (METERS)
C     BYCNTC = Y COORDINATE OF THE BASE CLOUD CENTROID FOR CARBON
C              PARTICLES FOR SIZE GROUP IDG FOR BURST IN AT TIME T
C              (METERS)
C     BZCNTC = Z COORDINATE OF THE BASE CLOUD CENTROID FOR CARBON
C              PARTICLES FOR SIZE GROUP IDG FOR BURST IN AT TIME T
C              (METERS)
C     BRTD   = RADIUS IN THE WIND TRACK DIRECTION FOR THE BASE CLOUD
C              DUST PARTICLES IN SIZE GROUP IDG FOR BURST IN AT TIME T
C              (METERS)
C     BRPD   = RADIUS IN THE DIRECTION PERPENDICULAR TO THE WIND TRACK
C              DIRECTION FOR THE BASE CLOUD DUST PARTICLES IN SIZE GROUP
C              IDG FOR BURST IN AT TIME T (METERS)
C     BRVD   = RADIUS IN THE VERTICAL DIRECTION FOR THE BASE CLOUD DUST
C              PARTICLES IN SIZE GROUP IDG FOR BURST IN AT TIME T
C              (METERS)
C     BRTC   = RADIUS IN THE WIND TRACK DIRECTION FOR THE BASE CLOUD
C              CARBON PARTICLES IN SIZE GROUP IDG FOR BURST IN AT TIME T
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C               (METERS)
C        BRPC    = RADIUS IN THE DIRECTION PERPENDICULAR TO THE WIND TRACK
C                  DIRECTION FOR THE BASE CLOUD CARBON PARTICLES IN SIZE
C                  GROUP IDG FOR BURST IW AT TIME T (METERS)
C        BRVC    = RADIUS IN THE VERTICAL DIRECTION FOR THE BASE CLOUD
C                  CARBON PARTICLES IN SIZE GROUP IDG FOR BURST IW AT TIME T
C                  (METERS)
C
C        OUTPUTS
C        TAUEA = OPTICAL DEPTH FOR EXTINCTION AT TIME T ALONG PATH BETWEEN
C                TRANSMITTER - RECEIVER IRT DUE TO MODE A DUST PARTICLES IN
C                SIZE GROUP IDG GENERATED BY BURST IW
C        TAUEB = OPTICAL DEPTH FOR EXTINCTION DUE TO MODE B DUST PARTICLES
C        TAUEC = OPTICAL DEPTH FOR EXTINCTION DUE TO CARBON PARTICLES
C        TAUSA = OPTICAL DEPTH FOR SCATTERING DUE TO MODE A DUST PARTICLES
C        TAUSB = OPTICAL DEPTH FOR SCATTERING DUE TO MODE B DUST PARTICLES
C        TAUSC = OPTICAL DEPTH FOR SCATTERING DUE TO CARBON PARTICLES
C        TAUAA = OPTICAL DEPTH FOR ABSORPTION DUE TO MODE A DUST PARTICLES
C        TAUAB = OPTICAL DEPTH FOR ABSORPTION DUE TO MODE B DUST PARTICLES
C        TAUAC = OPTICAL DEPTH FOR ABSORPTION DUE TO CARBON PARTICLES
C
C        OUTPUTS TO CDEPTH COMMON
C        TAUEW(IW,IRT) = TOTAL EXTINCTION OPTICAL DEPTH ALONG PATH IRT DUE
C                        TO ALL SIZE GROUPS AND MATERIALS FROM BURST IW
C        TAUSW(IW,IRT) = TOTAL SCATTERING OPTICAL DEPTH DUE TO BURST IW
C        TAUAW(IW,IRT) = TOTAL ABSORPTION OPTICAL DEPTH DUE TO BURST IW
C        TAUE(IRT)     = TOTAL EXTINCTION OPTICAL DEPTH ALONG PATH IRT DUE
C                        TO ALL MATERIALS IN ALL SIZE GROUPS AND ALL BURSTS
C        TAUS(IRT)     = TOTAL SCATTERING OPTICAL DEPTH
C        TAUA(IRT)     = TOTAL ABSORPTION OPTICAL DEPTH
C
         COMMON / CINPT2 / FREQ(10), XLAMDA(10), XT(10), YT(10), ZT(10),
        1                  XR(10), YR(10), ZR(10)
         COMMON / CINPT6 / NW, NDG, NRT, NTIME, NPROB, IPRINT
         COMMON / CPGRP / FNA(50), FNB(50), FNC(50), FMA(50), FMB(50),
        1                 FMC(50), PNGA(50), PNGB(50), PNGC(50),
        2                 CMUSA(50,10), CMUSB(50,10), CMUSC(50,10),
        3                 CMUEA(50,10), CMUEB(50,10), CMUEC(50,10),
        4                 CMUBA(50,10), CMUBB(50,10), CMUBC(50,10)
         COMMON / CTIME / XCENTD, YCENTD, ZCENTD, XCENTC, YCENTC, ZCENTC,
        1                 RTD, RPD, RVD, RTC, RPC, RVC, RS, HS, RT, RP,
        2                 RV, XCENTO, YCENTO, ZCENTO, BXCNTD, BYCNTD,
        3                 BZCNTD, BXCNTC, BYCNTC, BZCNTC, BRTD, BRPD,
        4                 BRVD, BRTC, BRPC, BRVC, BXCNTO, BYCNTO, BZCNTO,
        5                 BRT, BRP, BRV
         COMMON / CDEPTH / TAUEW(10,10), TAUSW(10,10), TAUAW(10,10),
        1                  TAUE(10), TAUS(10), TAUA(10)
         COMMON / CPATH / PMASSA, PMASSB, PMASSC, GMASSA, GMASSB, GMASSC
        1                , BPMASA, BPMASB, BPMASC, BGMASA, BGMASB, BGMASC
         COMMON / TAPE / ITAPE, JTAPE
C
C        COMPUTE THE OPTICAL DEPTH FOR EXTINCTION, SCATTERING, AND
C        ABSORPTION FOR THIS SIZE GROUP FOR EACH MATERIAL
C        COMPUTE OPTICAL PARAMETERS FOR THE MAIN CLOUD FIRST, THEN FOR THE
C        BASE CLOUD
         DO 105 ICLOUD = 1, 2
         IF( ICLOUD .EQ. 2 ) GO TO 5
C
```

```
C      MAIN CLOUD
       TAUEA = PMASSA * CHUEA(IDG,IRT)
       TAUEB = PMASSB * CHUEB(IDG,IRT)
       TAUEC = PMASSC * CHUEC(IDG,IRT)
       TAUSA = PMASSA * CHUSA(IDG,IRT)
       TAUSB = PMASSB * CHUSB(IDG,IRT)
       TAUSC = PMASSC * CHUSC(IDG,IRT)
       CHUAA = CHUEA(IDG,IRT) - CHUSA(IDG,IRT)
       CHUAB = CHUEB(IDG,IRT) - CHUSB(IDG,IRT)
       CHUAC = CHUEC(IDG,IRT) - CHUSC(IDG,IRT)
       TAUAA = PMASSA * CHUAA
       TAUAB = PMASSB * CHUAB
       TAUAC = PMASSC * CHUAC
       GO TO 7
C
C      BASE CLOUD
     5 TAUEA = BPMASA * CHUEA(IDG,IRT)
       TAUEB = BPMASB * CHUEB(IDG,IRT)
       TAUEC = BPMASC * CHUEC(IDG,IRT)
       TAUSA = BPMASA * CHUSA(IDG,IRT)
       TAUSB = BPMASB * CHUSB(IDG,IRT)
       TAUSC = BPMASC * CHUSC(IDG,IRT)
       TAUAA = BPMASA * CHUAA
       TAUAB = BPMASB * CHUAB
       TAUAC = BPMASC * CHUAC
C
C      SUM THE EXTINCTION, SCATTERING AND ABSORPTION CONTRIBUTIONS FROM
C      THE THREE MATERIALS
     7 TAUET = TAUEA + TAUEB + TAUEC
       TAUST = TAUS  + TAUSB + TAUSC
       TAUAT = TAUAA + TAUAB + TAUAC
C
C      ADD THE CONTRIBUTIONS TO THE TOTALS FOR EACH BURST AND FOR ALL
C      BURSTS
       TAUEH(IH,IRT) = TAUEH(IH,IRT) + TAUET
       TAUSH(IH,IRT) = TAUSH(IH,IRT) + TAUST
       TAUAH(IH,IRT) = TAUAH(IH,IRT) + TAUAT
       TAUE(IRT) = TAUE(IRT) + TAUET
       TAUS(IRT) = TAUS(IRT) + TAUST
       TAUA(IRT) = TAUA(IRT) + TAUAT
C
C      WRITE OUT THE DETAILED RESULTS UNLESS SUPPRESSED BY IPRINT OPTION
       IF( IPRINT .GT. 0 ) GO TO 105
       IF( IDG .EQ. 1 .AND. IRT .EQ. 1 .AND. ICLOUD .EQ. 1 ) GO TO 20
       XMSMAX = AMAX1( PMASSA, PMASSB, PMASSC )
       IF( ICLOUD .EQ. 2 ) XMSMAX = AMAX1( BPMASA, BPMASB, BPMASC )
       IF( XMSMAX .LE. 0. ) GO TO 105
       IF( NLINES .LT. 50 ) GO TO 60
       WRITE(JTAPE, 10)
    10 FORMAT(1H1,79H                                          DETAILED SIZ
      1E GROUP RESULTS (CONTINUED) )
       NLINES = 9
       GO TO 40
    20 WRITE(JTAPE, 30) NPROB, T, IH
    30 FORMAT(1H1,74H                                          ASL MUN
      1ITION DUST CLOUD MODEL //  1H ,
      263H                                                     PROBLEM NUMBER
      3 , I3 / 1H0,
```

```
     472H                                            DETAILED SIZE GROUP RESULTS F
     5OR TIME = , F6.1, 8H SECONDS / 1H ,
     672H
                                                                          BURST
     7 NUMBER = , I3 )
      NLINES = 15
   40 WRITE(JTAPE, 50)
   50 FORMAT(1H0 / 1H0,
     1126HCLOUD     DUST       CARBON   DUST RADII  CARBON RADII  TOTAL M
     2ASS   CLOUD   GROUP MASS   OPTICAL DEPTH ALONG PATH DUE TO GROUP /
     31H ,
     4125H         CENTROID   CENTROID  WIND TRACK  WIND TRACK    IN GROU
     5P                PENETRATED   EXTINCTION   SCATTERING   ABSORPTION /
     61H ,
     7113HGROUP    X-COORD.   X-COORD.  CROSS TRACK CROSS TRACK   DUST-MO
     8DE A    PATH   DUST-MODE A                      DUST-MODE A / 1H ,
     9113HNUMBER  Y-COORD.   Y-COORD.   VERTICAL    VERTICAL      DUST-MO
     1DE B  NUMBER  DUST-MODE B                       DUST-MODE B / 1H ,
     2110H         Z-COORD.   Z-COORD.   (METERS)    (METERS)       CARBO
     3N                CARBON                           CARBON / 1H ,
     4 85H         (METEPS)    (METERS)                             (GRAM
     5S)                (GM/CM2) )
   60 IF( XMSHA  .GT. 0. ) GO TO 65
      IF( IRT .EQ. 1 .AND. IDG .EQ. 1 ) GO TO 65
      GO TO 105
   65 IF( ICLOUD .EQ. 2 ) GO TO 80
      WRITE(JTAPE, 70) XCENTD, XCENTC, RTD, RTC, GMASSA, PMASSA, TAUEA,
     1                  TAUSA, TAUAA, IDG, YCENTD, YCENTC, RPD, RPC,
     2                  GMASSB, IRT, PMASSB, TAUEB, TAUSB, TAUAB, ZCENTD,
     3                  ZCENTC, RVD, RVC, GMASSC, PMASSC, TAUEC, TAUSC,
     4                  TAUAC
   70 FORMAT(1H0, 4HMAIN, 2F11.1, 2F12.1, 1PE14.2, 5X, 4HMAIN, 1PE12.2,
     1 3E13.2/ 1H , I3, 0PF12.1, F11.1, 2F12.1, 1PE14.2, I7, E14.2,
     2 3E13.2,/ 1H , 0PF15.1, F11.1, 2F12.1, 1PE14.2, E21.2, 3E13.2 )
      GO TO 100
   80 WRITE(JTAPE, 90) BXCNTD, BXCNTC, BRTD, BRTC, BGMASA, BPMASA, TAUEA
     1                , TAUSA, TAUAA, IDG, BYCNTD, BYCNTC, BRPD, BRPC,
     2                  BGMASB, IRT, BPMASB, TAUEB, TAUSB, TAUAB, BZCNTD,
     3                  BZCNTC, BRVD, BRVC, BGMASC, BPMASC, TAUEC, TAUSC,
     4                  TAUAC
   90 FORMAT(1H0, 4HBASE, 2F11.1, 2F12.1, 1PE14.2, 5X, 4HBASE, 1PE12.2,
     1 3E13.2/ 1H , I3, 0PF12.1, F11.1, 2F12.1, 1PE14.2, I7, E14.2,
     2 3E13.2,/ 1H , 0PF15.1, F11.1, 2F12.1, 1PE14.2, E21.2, 3E13.2 )
  100 NLINES = NLINES + 4
  105 CONTINUE
      IF( IW .EQ. NW .AND. IDG .EQ. NDG .AND. IRT .EQ. NRT ) GO TO 110
      GO TO 240
C
C     ALL CALCULATIONS ARE COMPLETE FOR THIS TIME. WRITE OUT SUMMARY OF
C      RESULTS FOR EACH PATH
  110 WRITE(JTAPE, 120) NPROB, T
  120 FORMAT(1H1,59H                                    ASL MUNITION DUST CLOU
     1D MODEL // 1H0,
     248H                                       PROBLEM NUMBER , I3 / 1H0,
     362H                          SUMMARY OF PROPAGATION RESULTS FOR TIME =,
     4F6.1, 8H SECONDS // )
      NLINES = 11
C
      DO 230 KRT = 1, NRT
```

```
C
C     CALCULATE THE TRANSMISSIONS CORRESPONDING TO THE TOTAL OPTICAL
C     DEPTHS
      TRANE = 0.
      TRANS = 0.
      TRANA = 0.
      IF( TAUE(KRT) .LT. 40. ) TRANE = EXP( - TAUE(KRT) )
      IF( TAUS(KRT) .LT. 40. ) TRANS = EXP( - TAUS(KRT) )
      IF( TAUA(KRT) .LT. 40. ) TRANA = EXP( - TAUA(KRT) )
C
      DO 220 KW = 1, NW
      IF( KRT .EQ. 1 .AND. KW .EQ. 1 ) GO TO 150
      IF( NLINES .LE. 50 ) GO TO 170
      WRITE(JTAPE, 140)
  140 FORMAT(1H1,63H                           SUMMARY OF PROPAGATION RESULTS
     1(CONTINUED) // )
      NLINES = 8
  150 WRITE(JTAPE, 160)
  160 FORMAT( 1H0,
     1 97H          WAVELENGTH  PATH COORDINATES(METERS)     TOTAL       T
     2OTAL OPTICAL  OPTICAL DEPTH CONTRI- / 1H ,
     3 99H PATH     (MICRONS)  TRANSMITTER   RECEIVER    TRANSMISSION
     4  DEPTH        BUTIONS FROM EACH BURST / 1H ,
     5 99HNUMBER  FREQUENCY      X-COORD.    X-COORD.     EXTINCTION
     6EXTINCTION     BURST   EXTINCTION / 1H ,
     7 94H            (GHZ)       Y-COORD.    Y-COORD.     SCATTERING
     8SCATTERING     NUMBER  SCATTERING / 1H ,
     9 94H                        Z-COORD.    Z-COORD.     ABSORPTION
     1ABSORPTION               ABSORPTION  )
  170 IF( KW .GT. 1 ) GO TO 190
      WRITE(JTAPE, 180) KRT, XLAMDA(KRT), XT(KRT), XR(KRT), TRANE,
     1                  TAUE(KRT), KW, TAUEW(KW,KRT), FREQ(KRT),
     2                  YT(KRT), YR(KRT), TRANS, TAUS(KRT),
     3                  TAUSW(KW,KRT), ZT(KRT), ZR(KRT), TRANA,
     4                  TAUA(KRT), TAUAW(KW,KRT)
  180 FORMAT(1H0, I3, F13.1, F14.1, F11.1, 1PE16.2, E15.2, I8, E14.2 /
     1 1H , 1PE16.2, 0PF14.1, F11.1, 1PE16.2, E15.2, E22.2 /
     2 1H , 16X, 0PF14.1, F11.1, 1PE16.2, E15.2, E22.2 )
      GO TO 210
  190 WRITE(JTAPE, 200) KW, TAUEW(KW,KRT), TAUSW(KW,KRT), TAUAW(KW,KRT)
  200 FORMAT(1H0, 72X, I8, 1PE14.2 /
     11H , 80X, 1PE14.2/
     21H , 80X, 1PE14.2 )
  210 NLINES = NLINES + 5
C
  220 CONTINUE
C
  230 CONTINUE
C
  240 RETURN
      END
```

```
      SUBROUTINE ADDVEC( V1, V2, V3 )
C
C     THIS ROUTINE ADDS TWO THREE VECTORS TOGETHER
C
C     INPUTS
C     V1 = FIRST THREE VECTOR
C     V2 = SECOND THREE VECTOR
C
C     OUTPUT
C
C     V3 = THREE VECTOR WHICH IS THE SUM OF V1 AND V2
C
      DIMENSION V1(3), V2(3), V3(3)
C
      DO 10 I = 1, 3
      V3(I) = V1(I) + V2(I)
   10 CONTINUE
C
      RETURN
      END
```

```
      SUBROUTINE SUBVEC( V1, V2, V3 )
C
C     THIS ROUTINE SUBTRACTS TWO THREE VECTORS
C
C     INPUTS
C     V1 = FIRST THREE VECTOR
C     V2 = SECOND THREE VECTOR
C
C     OUTPUT
C     V3 = THREE VECTOR WHICH IS V1 - V2
C
      DIMENSION V1(3), V2(3), V3(3)
C
      DO 10 I = 1, 3
      V3(I) = V1(I) - V2(I)
   10 CONTINUE
C
      RETURN
      END
```

```
      SUBROUTINE MULVEC( V1, S, V3 )
C
C     THIS ROUTINE MULTIPLIES A THREE VECTOR BY A SCALAR
C
C     INPUTS
C     V1 = THREE VECTOR
C     S   = A SCALAR
C
C     OUTPUT
C     V3 = THE THREE VECTOR RESULTING FROM MULTIPLYING V1 BY S
C
      DIMENSION V1(3), V3(3)
C
      V3(1) = S * V1(1)
      V3(2) = S * V1(2)
      V3(3) = S * V1(3)
C
      RETURN
      END
```

```
      SUBROUTINE DOTVEC( V1, V2, S )
C
C     THIS ROUTINE CALCULATES THE DOT PRODUCT OF TWO THREE VECTORS
C
C     INPUTS
C     V1 = FIRST THREE VECTOR
C     V2 = SECOND THREE VECTOR
C
C     OUTPUT
C     S  = SCALAR DOT PRODUCT OF V1 AND V2
C
      DIMENSION V1(3), V2(3)
C
      S = V1(1) * V2(1) + V1(2) * V2(2) + V1(3) * V2(3)
C
      RETURN
      END
```

```
      SUBROUTINE DSTVEC( V1, V2, DIST )
C
C     THIS ROUTINE CALCULATES THE DISTANCE BETWEEN THE ENDPOINTS OF
C     VECTORS V1 AND V2
C
C
C     INPUTS
C     V1 = FIRST THREE VECTOR
C     V2 = SECOND THREE VECTOR
C
C     OUTPUT
C     DIST = DISTANCE BETWEEN ENDPOINTS OF VECTORS V1 AND V2
C
      DIMENSION V1(3), V2(3)
C
      DIST = SQRT( ( V1(1) - V2(1) ) ** 2 + ( V1(2) - V2(2) ) ** 2
     1           + ( V1(3) - V2(3) ) ** 2 )
C
      RETURN
      END
```

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